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SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

VOL. II.—BARYTES AND WITHERITE

BY

G. V. WILSON, B.Sc., T. EASTWOOD, A.R.C.S.
R. W. POCOCK, B.Sc., D. A. WRAY, M.Sc.,
AND T. ROBERTSON, B.Sc.

WITH CONTRIBUTIONS BY

H. G. DINES, A.R.S.M.

THIRD EDITION.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

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PREFACE.

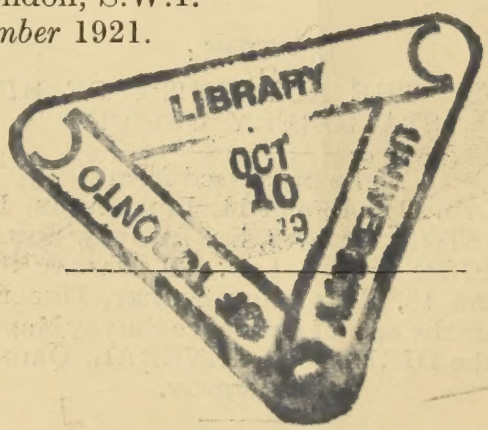
The first edition of this memoir, which was published in 1915, was written by R. G. Carruthers, T. Eastwood, G. V. Wilson, R. W. Pocock, D. A. Wray, H. Dewey, and C. E. N. Bromehead. In 1916 a second edition appeared, by the same authors. The exhaustion of the second edition afforded an opportunity for a complete revision of the information, but several of the authors of earlier editions were no longer available, and their names are, accordingly, omitted from the title page. All the principal mines have been revisited, and the accounts of output and workings brought up to date as far as possible. Mr. Wilson contributes the chapter on Scotland; Messrs. Eastwood and Wray describe the deposits of the six northern counties; Mr. Pocock deals with the mines of Shropshire, Wales and the Welsh Border; Mr. Robertson supplies the account of Derbyshire, and Mr. Dines that of Devon and Somerset; Messrs. Wray and Dines also describe some of the mines of North Wales.

We have in all cases to acknowledge our indebtedness to the owners and managers for their cordial co-operation during the visits to their mines. To Col. J. V. Ramsden, D.S.O., and Mr. T. C. F. Hall of the Shropshire Mines, Ltd., we are specially indebted for maps and reports of the mines of Shropshire and Montgomeryshire. Our thanks are also due for the great assistance rendered in Cumberland by Messrs. Reynoldson, Robinson, Davis and Porter.

The work of editing the memoir has been carried out by Mr. Henry Dewey.

JOHN S. FLETT,
Director.

Geological Survey Office,
28, Jermyn Street,
London, S.W.1.
6th September 1921.



Daily Mail 3/3/22

Tiles made of baryta presented to academy of Medicine Paris. Claimed that impervious to X rays.

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BARYTES AND WITHERITE

CHAPTER I.

INTRODUCTION.

Characters of the Minerals.

Barytes, barite, heavy spar or barium sulphate ($BaSO_4$) contains 65·7 per cent. of barium oxide or baryta (BaO). It is a rhombic mineral, commonly found in massive platy aggregates, easily cleaved, with either straight or curved surfaces, but, exceptionally, an earthy or a fibrous banded habit may be assumed (Derbyshire). When able to grow freely, beautiful crystals result, often tabular, with deeply bevelled edges. In colour the mineral, when pure, varies from opaque white to water-clear, but is frequently stained, especially with red or brown ferruginous compounds, which may be either superficial or disseminated throughout the spar.

Barytes has a white streak, and in hardness (3 to 3·5) is similar to, or slightly greater than, calcite, a mineral with which it is commonly associated and sometimes confused; but barytes is nearly twice as heavy as calcite (the specific gravity being 4·5), and it does not effervesce with acid.

In this country barytes is pre-eminently a vein-mineral. It is a common constituent of mineral-lodes, especially those carrying lead- and zinc-ores, and in these cases is generally associated with varying proportions of calcite, quartz or fluorspar, though many veins are known in which barytes occurs practically alone. In Germany (the world's chief producer) most of the spar also comes from mineral veins, but the United States have extensive surface-deposits in which it is a residual product of limestone-weathering. These latter deposits can be paralleled on a minor scale at Bradwell Moor, Derbyshire (p. 65). At Nutfield, in Surrey, barytes occurs in isolated crystalline masses embedded in "fuller's earth."

Witherite or barium carbonate ($BaCO_3$) carries 77·6 per cent. of barium oxide (BaO). Like barytes, it is a rhombic mineral, and is sometimes seen in well-developed six-sided crystals, but generally occurs in pale yellowish-green spheroidal or compact masses, translucent, with a platy surface, a radiate structure and waxy lustre. Such masses commonly have a dull outer crust, and may contain small amounts of strontium carbonate. Witherite has much the same hardness and specific gravity as barytes, but is soluble in hydrochloric acid, if not too concentrated, though the effervescence is less violent than with calcite.

The mineral is relatively rare; it is generally isolated in

pockets along the course of barytes veins, though occasionally it is disseminated in small particles throughout a lode. In Britain only three workable veins, with witherite as the main constituent, are known. These occur at Settlingstones and Fallowfield, in Northumberland, and at Ushaw Moor, in Durham.

Sources of Supply.

The chief centres for barytes and witherite are situated in Northumberland, Durham, Westmorland, Shropshire and the Welsh Border: while subsidiary quantities are obtained in Cumberland, Yorkshire, Derbyshire, Flint, Montgomeryshire, Carmarthenshire, Devon and Somerset.

Most of the North of England spar occurs in veins traversing the upper strata of the Carboniferous Limestone Series, with the important exceptions of New Brancepeth and Ushaw Moor, in which the Coal Measures form the country-rock. Around Wolsingham the country-rock invariably consists of the Millstone Grit, while the Cumberland veins traverse the Lower Palæozoic rocks. On the whole, the barytes is of good quality, and in certain cases, of very high grade. Many of the mines have their own grinding-mills, and any bleaching required is confined to the small lump.

The Shropshire and Welsh Border district yields spar of good quality, from veins in the Lower Palæozoic rocks. Here, again, bleaching is generally confined to the small lump, and most of the grinding is done at three local mills.

The Derbyshire barytes is practically all discoloured and of low grade. The deposits occur in the Carboniferous Limestone, and are remarkable for the intermixture of an amorphous, earthy-looking barytes with the ordinary crystalline type. In some cases the latter is almost entirely absent. The specific gravity of the amorphous variety is appreciably lower than that of the crystalline. Much of the Derbyshire barytes is intimately associated with fluorspar, the two minerals forming a fine-grained granular aggregate.*

Commercial Uses.

The commercial uses of barytes are largely dependent on the fact that it is a heavy white mineral, cheap, and chemically inert. The market price depends not so much on purity as on colour, and the grades produced are arranged on that basis. The finest quality white powder is used in the preparation of white paints, for wall-papers, for "bleaching" flannel, shoddy cloth and Austrian flour, while inferior darker grades are extensively used in the manufacture of lithopone (a paint composed of a variable mixture of zinc oxide, zinc carbonate, zinc sulphide and barium sulphate), and in asbestos goods. American reports indicate

* In Derbyshire "the calk, feagh, spar, and other minerals, and rubbish (except lead ore)" are at the disposal of the landowner. ("The Miners' Guide," Wirksworth, 1852, p. 4.)

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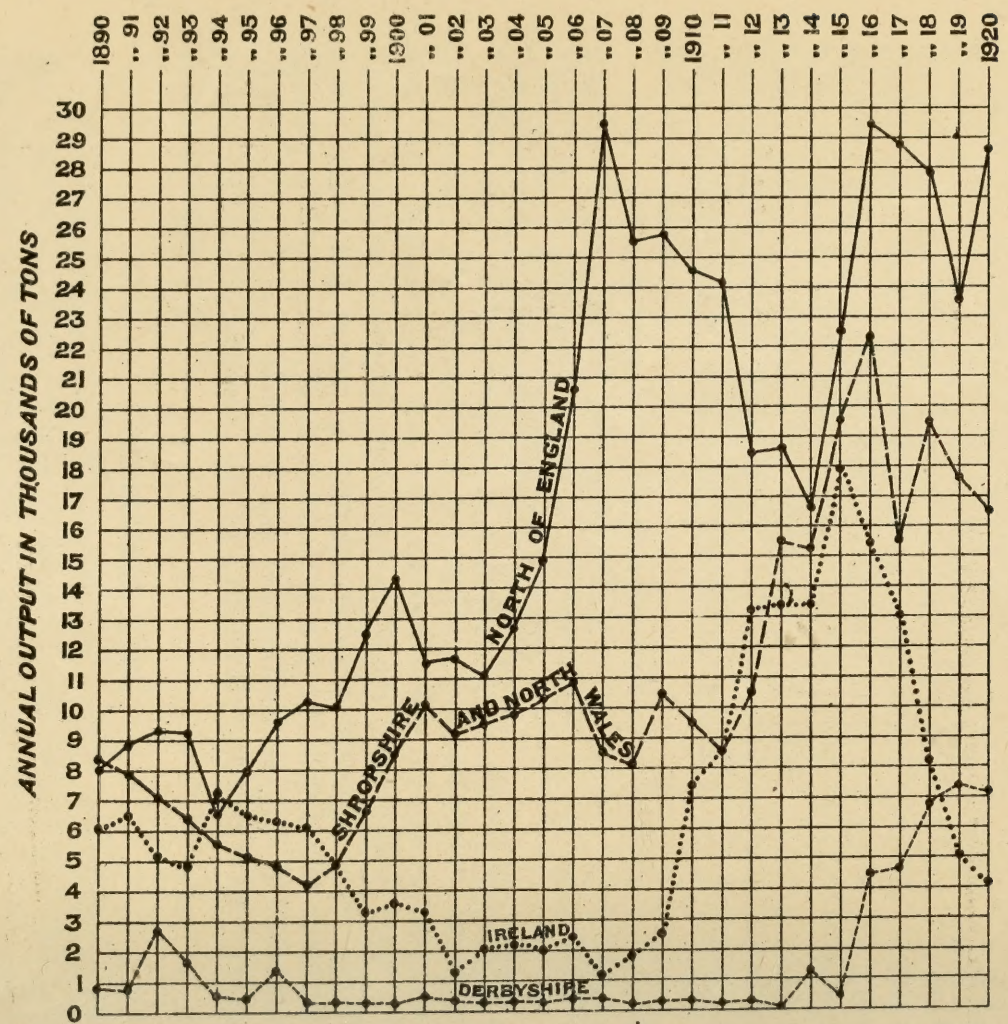


OUTPUT OF BARIUM MINERALS FROM THE LEADING DISTRICTS OF ENGLAND, WALES & IRELAND.

Charles & Read, Ltd. *Photolitho*, 548.

15589. $\frac{5}{18}$/585. 1000.

that the mineral is also used for making "artificial ivory," fertilizers, boiler-compounds, insecticides, peroxide of hydrogen, and "artificial driftwood salts."

In the preparation of the finer pigments it is essential that the barytes should be not only a good white, but also that it should be very finely ground. To attain this object most British producers pass the ground spar through finishing french buhr stones two or even three times, but a still finer state of subdivision seems to be desirable. In this respect German barytes, which had been imported in rapidly increasing quantities before the war, and is now again entering the country in large quantities, has frequently surpassed the home product. British barytes producers are now alive to this fact, and with improved methods of grinding are supplying as fine, if not a finer, product than the German.

Witherite is in chief demand as a mineral from which all kinds of barium compounds can readily be made; the commercial grading is therefore quite different from that of barytes, and is based on its state of chemical purity. There seems to be no important use for the carbonate as such, although it has been tried as a preventative of efflorescence on bricks. The mineral is sold directly to chemical manufacturers as "crude lump," and subsequently converted to barium chloride, oxide, nitrate and other salts. In particular, witherite, chemically converted into sulphate, gives a precipitated barytes which is in a finer state of subdivision than can ever be attained by grinding the native mineral. This "blanc-fixé," or "blanc-white," is used in the preparation of polished white cards, papers, etc. Witherite is used also in the preparation of barium peroxide, which is employed in the commercial production of oxygen by Brin's process. Still further uses appear in the treatment of wallpapers, and in coating oil-cloths and linoleum, while small quantities are in demand for glazing pottery, and enamelling iron and steel. It has also been employed in the glass-industry, and formerly in sugar-refining, in which however it has been largely replaced by strontianite owing to its poisonous nature, a characteristic which has led to its being made a constituent of rat-poisons.

Industrial Notes.

There has been a steady increase in the home-consumption of barytes, but the demand is by no means reflected in the output from individual districts. That such is the case will be noticed from an inspection of Plate I., in which there is an analysis of the leading English and Irish outputs for the last 31 years. The remarkable fluctuations apparent in every district, and the lack of any agreement between them, a rise in one region frequently corresponding with a depression in another, is probably due to the fact that the number of working mines is small, so that the operations of a single plant may profoundly affect the output for the whole district. A case in point is the extraordinary increase

in the North of England production in 1907. In that year New Brancepeth raised some 10,000 tons of spar, more than half the total for the whole region; and at all times this mine, averaging 4,000 tons a year, has a great influence.

Similarly the rise in the output of the Shropshire and Welsh Border District in 1899, would be due in large measure to the opening of the Snailbeach Mine at that date, and the further rise in 1909 probably came from the reopening of the Bog Mine (one of the chief producers) a year previously.

The foregoing remarks are offered lest an inspection of Plate I. should give the impression that the demand for barytes is subject to abrupt local fluctuations. The local output certainly is so subject, as the diagram shows, but that is affected by matters that have nothing to do with the demand, such as water-trouble, deterioration or improvement in spar-bodies, etc.

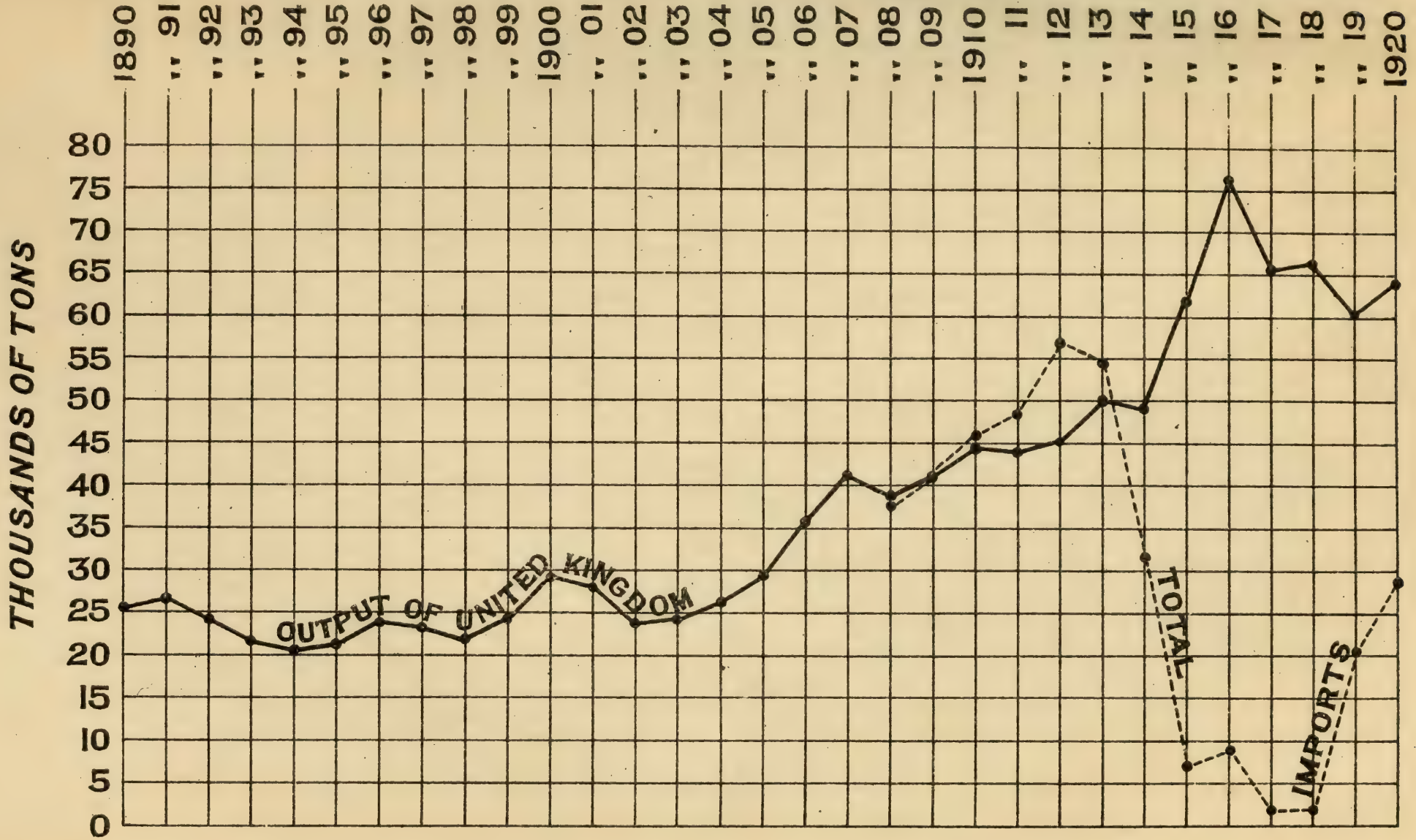
Better evidence of the steady improvement in demand since 1902 is supplied by the statistics of output of the United Kingdom as a whole, coupled with those relating to the imports. Unfortunately the latter are only available for the last 13 years. Plate II. shows that since 1908 the home output rose nearly continuously to a maximum in 1916, but in 1914 the imports fell to an almost negligible figure, the result being a considerable shortage. Since 1918 the imports have increased, while the home production has declined.

The output of witherite (Plate III.) calls for little remark because it is exceedingly localised and the demand is relatively small. In 1913, 100 tons were produced in Flintshire, the first since 1891, and small amounts in following years. Occasional small quantities are obtained from Cumberland and Durham, but Northumberland has always been the principal contributor. The total output of this county has fluctuated between 3,500 and 10,500 tons, the maximum being in 1910.

The following pages contain detailed accounts of the mines, both active and idle; they are arranged, as far as possible, in counties, to each of which a short introductory note is prefixed, describing the principal characters of the district, and any peculiarities it may possess.

Of the six-inch maps referred to in the following pages, those marked P. are published with engraved geological lines; those marked Ms. are not so published, but manuscript copies can be consulted in the Library of the Geological Survey, and can be supplied at the cost of drawing and colouring.

The six-inch maps marked Ord. are of areas that have been surveyed geologically only on the scale of one inch to the mile.



TOTAL OUTPUT OF BARIUM MINERALS IN THE UNITED KINGDOM & TOTAL IMPORTS.

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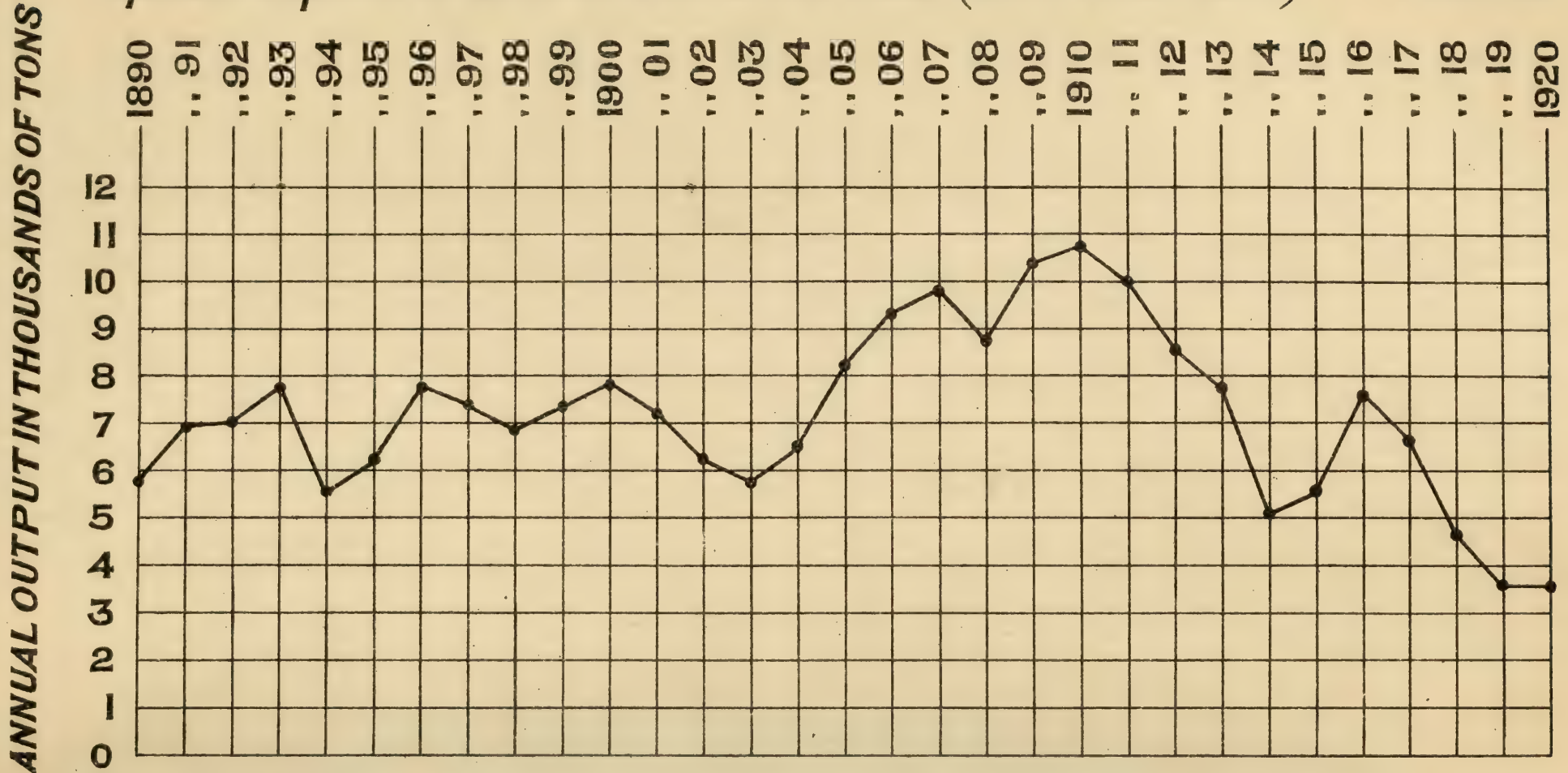

OUTPUT OF WITHERITE IN THE UNITED KINGDOM.

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CHAPTER II.

THE MINES OF THE SIX NORTHERN COUNTIES.

I.—Northumberland.

General Account.

Northumberland yields little barytes, but has always been the chief producer of witherite in Britain. The supply is strictly localised (*see* Plate IV.). The mines are situated near the junction of the North and South Tyne rivers above Hexham, and are all on galena-bearing veins, trending in a N.E. and S.W. direction. The veins occur in both the Carboniferous Limestone Series and the Whin Sill, which in this district is 28 fms. thick, and lies at the base of the Scar Limestone. Generally speaking, the Whin Sill has never been productive for metallic ores, but the Settlingstones and Stonecroft mines form notable exceptions, for practically the whole of the witherite mined at present comes from that rock. The Settlingstones Mine is the only one now working, but it has frequently been stated that if the Northumbrian mines were deepened, such thick limestone-beds as occur further south might be met with, and that these should carry good ore- and spar-bodies. But a few miles north of the mines all these lower strata outcrop, and the equivalents of the thick Yorkshire limestones are largely represented by massive grits and sandstones, with intercalated beds of shale and coal, while the few limestones seen are all thin and poor. It does not necessarily follow, however, that to deepen the abandoned mines would be a useless proceeding.

Witherite occurs in the form of gigantic lenses, or "swells," rather than in regular veins. Both at Fallowfield and at Settlingstones the horizontal extent of the spar is restricted, but the bottom has not been reached.

Details of Mines.

Settlingstones Mine.

Settlingstones Mines Company, 4, St. Nicholas Buildings, Newcastle-on-Tyne.

The mine is three miles west of Fourstones Station (N.E.R.). and about six and a half miles north-west of Hexham.

Maps.—One-inch New Series Ordnance, 13; Old Series Geological, 106 N.E.; six-inch Northumberland, 84 S.W., S.E., Ms.

Although several veins occur which generally follow a north-easterly direction through the limestones and shales of the Carboniferous Limestone Series, only one, the Settlingstones Main Vein, is being worked. It is almost vertical, with a slight inclination to the south, and follows the course of a prominent fault with a downthrow of about 96 ft. to the south. The

Settlingstones Main Vein is unique in containing exclusively nearly pure witherite, the other minerals, calcite, barytes, and galena, being in small quantities. At Settlingstones the Whin Sill appears to be interstratified in the Carboniferous Limestone Series, and attains a thickness of 28 fms. at or about the horizon of the floor of the Scar Limestone.

The vein can only be seen at the surface at the eastern end of the workings where it crosses the Settlingstones Burn. Here the Whin Sill forms its north cheek, while the southern cheek consists of limestone. At the western end the vein is obscured by a thick covering of boulder clay, which at the Frederick Shaft is no less than 180 ft. thick.

The width of the vein is fairly constant, and averages about 10 ft. The vein has been followed over a total horizontal distance of about 2,000 yds. in a south-westerly direction from Settlingstones Burn. The present southern limit of the workings is about 100 yds. north-east of the old Grindon Hill Mine Shaft, or about 1,000 yds. distant from the Frederick Shaft. In a north-easterly direction the vein has been followed to the Winter Shaft, near Settlingstones House, where it is intercepted by a north and south galena-bearing vein, formed in a fault with a downthrow to the east. Still further north-east the vein becomes less productive of witherite, but has been tried for galena.

Witherite is being mined between the 80- and the 117-fm. levels, where the vein is richest and is wholly in the Whin Sill. Above the 80-fm. level in the limestones, plates, and hazels, the witherite deteriorates considerably, and will not repay extraction.

At the present working-face, 1,000 yds. south-west of the Frederick Shaft, the vein is about 6 ft. wide, and consists almost wholly of pure translucent, yellowish-brown, crystalline witherite. Fifty yds. to the north-east of the present face the vein attained the abnormal width of 36 ft.; while this mainly consisted of witherite, large lenses of pure galena were met with towards the centre. At this point the vein gives off a prominent side shoot, 3 ft. wide, which rejoins the vein. These branches, known locally as "horses," yield very pure witherite. Numerous similar rich lenses and shoots have been met with in working the Settlingstones Vein in the past.

The amount of water pumped from the workings is about 600 gallons a minute. This is raised to a level, 13 fms. from the surface, and thence drains away through an adit into the neighbouring stream, from which water for washing purposes is available, except in unusually dry summers.

The higher grades of witherite mined consist of slightly yellow or brownish-white crystalline masses, with a waxy lustre, and yield from 95 to 100 per cent. of barium carbonate. The witherite is first hand-picked, and the cleanest and highest grade material removed. Some of this is sufficiently pure to be sent away to the market; the remainder is sized to $1\frac{1}{8}$ in. pieces on a perforated table, and then passed to a specially devised series of

BARYTES & WITHERITE AREAS OF THE N. OF ENGLAND.

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jigs, which at one operation sort the material into pieces of less and more than ¼ in. size, and also separate the refuse. By this means raw material with about 60 to 70 per cent. of barium carbonate is concentrated to about 93 per cent. of barium carbonate in the lump-witherite, and about 83 to 84 per cent. in the "smalls." Any mineral that is not treated by the above process, and is not of the first quality, goes to another set of machines, where it is crushed so as to pass through a ¼-in. mesh, and transferred to a series of jigs. This process is slow, and necessitates the use of a Blake's crusher, sizing trommels, and two chatt mills or rollers; the material has also to pass through five sizing trommels before reaching the jigs. Large pieces are returned to the rollers, and must pass through the ¼-in. mesh before being conveyed to the jigs for dressing. The mineral thus treated contains about 40 per cent. of barium carbonate previous to treatment, and about 83 per cent. when finished.

The three grades of witherite sent away are as follows:—highest grade hand-picked "lump" containing from 93 per cent. to 100 per cent. of barium carbonate; second grade "lump" with about 90 to 93 per cent., and third grade, or "smalls," with 79 to 84 per cent.

All grades are sold on the so-called "unit" system, in which the price is regulated by the actual amount of barium carbonate in the material as indicated by analysis of typical samples.

The mine was originally worked for lead-ore, but witherite has been obtained for many years. Between 1870 and 1880, 1,500 to 3,000 tons were produced annually. During the next 30 years there was an average of about 4,000 tons per annum, and for the past few years the annual output has ranged from 5,000 to 7,000 tons. The highest output amounted to nearly 10,000 tons in 1910.

It is estimated that, at the present rate of output, there is proved ground available for 40 years' working, and that with the existing arrangements it would be possible to produce upwards of 15,000 tons a year. Some of the witherite is exported.

Stonecroft Mine.

Mr. P. O. Laidlaw, Stonecroft House, Fourstones.

Stonecroft mine is 2¼ miles W.N.W. from Fourstones Station (N.E.R.), and 1,000 yds. N.W. of Stonecroft House.

Maps.—One-inch New Series Ordnance, 13. Old Series Geological, 106 N.E.; six-inch Northumberland, 84 S.E., Ms.

Stonecroft, originally a lead mine, ceased work in 1896, after being in operation for nearly half a century.

There are several lodes, which are fissure-veins along lines of fault with downthrows south. Of these, the North and the South Cross Veins and the North-West Vein run in a north-west direction, and are intersected by the Stonecroft Main Vein, which trends E. 16° N.

The Stonecroft Main Vein follows the course of a prominent fault with a downthrow of about 15 fms. south. Its maximum width is 8 ft., and the total depth of the workings 70 fms, where the base of the Whin Sill is reached. As at Settlingstones the Whin Sill occurs at the base of the Scar Limestone. The gangue in the Stonecroft Vein was a mixture of country-rock, barytes, and quartz, with some pockets of witherite. The ore gave out in the shale beneath the Whin Sill, as commonly happens in this area. Occasional rich lenses and "horses," or branches, which yielded much high-grade witherite occurred in connection with the Stonecroft Vein as at the Settlingstones Mine. The water pumped from the Stonecroft Mine averaged from 700 to 800 gallons per minute.

An important vein, occurring immediately south of and parallel with the Stonecroft Main Vein is the South Vein. It has been worked both at the Stonecroft and Settlingstones Mines. From an old working near the workshops at Settlingstones, 150 yds. south-west of the intersection of the Settlingstones Main Vein and Settlingstones Burn, a cross-cut was driven 100 yds. in a south-easterly direction to reach the South Vein. At this point the South Vein averaged 4 ft. in width, and contained no galena and only poor quality barytes. The poverty of the vein, combined with the cost of pumping led to the abandonment of the workings.

Although the output at the Stonecroft Mine consisted almost wholly of galena, a little witherite was wrought when there were sufficiently large bodies of it in the gangue. Thus in 1880, 4 tons; in 1882, 3 tons; and in 1896, the last year of working, 97 tons of witherite were produced. Practically all of it came from the lower levels.

Walwick Fell and Tepper Moor.

Maps.—One-inch New Series Ordnance, 13; Old Series Geological, 106 N.E.; six-inch Northumberland, 84 N.E., Ms.

In the neighbourhood of Walwick Fell, and about $1\frac{1}{4}$ miles E.N.E. of Stonecroft Mine, a vein has been exploited in the past century. It extends in a north-easterly direction from near the southern side of Walwick Fell to Meggie's Dean Burn, 700 yds. W.S.W. of Torney's Fell. It is thought to be a continuation of the Stonecroft Main Vein. The main shaft, 60 fms. deep, is 270 yds. east of Torney's Fell, and at this point the vein, 4 ft. wide, is reported to have consisted mainly of barium spars, and to have been unprofitable for working lead-ore. The workings are about the horizon of the Whin Sill, in the Scar Limestone. The dumps yield high-grade witherite and barytes, together with other vein-matter and galena.

The Tepper Moor lead mines, which were last worked some 20 years ago, lie two miles north of the Settlingstones Mine, and about 4 miles north-west of Fourstones Station (N.E.R.). A

N.E. and S.W. vein, carrying mainly barytes with some lead-ore, crosses Crook Burn, and the old workings occur 1,000 yds. north-west of Tepper Moor House. The vein consists of a succession of swells, or lenses, and pinches in places to less than 1 ft. in width. High quality barytes is abundant on the dumps.

Fallowfield Mine.

Messrs. Walton and Cowper, Acomb, Hexham.

Fallowfield Mine is situated about three-quarters of a mile south-east of Fallowfield, 1 mile north of Acomb, and about 2½ miles north of Hexham.

Maps.—One-inch New Series Ordnance, 13; Old Series Geological, 106 N.E.; six-inch Northumberland, 85 S.W., S.E., Ms.

The Fallowfield Vein, whose chief constituents are witherite, barytes, and galena, occurs along the course of a large fault trending in a north-easterly direction, with a downthrow north of 50 to 60 fms., and an average dip of 1 in 3, or 19°. It runs through the Upper Yoredale beds. Fallowfield was formerly an important lead mine, and the centre of the vein where the galena chiefly occurred has, in consequence, been extensively "slit." The part richest in barium spars extended from Coldlaw-dean to the New or Low Engine Shaft* at Halfway House, a total horizontal distance of 2,000 yds. The breadth varied from 20 to 40 ft., including bands of country rock, and there were ribs of solid spar 5 to 6 ft. wide, of which 60 to 70 per cent. was pure witherite. The maximum depth of the spar-workings was 60 fms. The various "sills" in contact with the veins had no great effect on their contents, although barium spars were generally better developed at the horizon of the limestones and the "hazels," or sandstones. The Great Limestone, on the north cheek of the vein, was stated to be the richest level, but neither there, nor at any part of the workings, were there any "flats" or horizontal stringers of spar.

Witherite was the main product of this mine; it was found in pockets, and was pure and translucent, with a white or pale yellowish-green tinge. Some of the clusters were beautifully crystalline. Barytes was subordinate in quantity, was commonly flesh-coloured, and stated to be of no great value. Galena occurred in small pockets scattered through the spars, but, as noted above, was chiefly concentrated in the centre of the vein.

No quartz was found, but calcite was relatively abundant round the Old Engine Shaft, where it rose to 10 per cent. of the total spar-body, the average for the whole mine being about 2½ per cent.

The vein has been proved for a distance of 1¾ miles, from the Wall-Acomb high road up to the Coldlaw road, where it

* In the published 6-inch map, Northumberland 85 S.W., the position of the Old and New Engine Shafts has been transposed in error.

became stringy and finally died out. Some confusion was also caused by an intersecting lead-bearing vein. The Old Engine Shaft was sunk vertically for 86 fms., but although spar was not wrought below 60 fms., some galena was worked. The lead miners, who had "slit" the vein so extensively, packed their waste with spar, which constituted an easily obtained source of supply for a prolonged period. The water draining from this mine averaged 350 gallons per minute, but while the mine was in operation it does not appear to have presented a serious obstacle. A reopening of the mine below the 60-fm. level in the rich section between Coldlawdean and the Low Engine Shaft would require much outlay. At the time the mine was closed down there was no evidence of deterioration of the spar bodies in depth.

After washing, the best lump-spar, of 1-in. diameter and upwards, was removed by hand-picking, and the remainder sent through roller-sieves, and jigged to remove galena and dirt. With these jigs there were four tubs which took off in order "tub galena," "ordinary lump" with from 92 to 94 per cent. of barium carbonate, "small pieces" with from 86 to 90 per cent., "best smalls" with from 80 to 85 per cent., "second smalls" with 70 per cent., and "slimes and sludges," with 60 per cent.

Fallowfield is believed to have been a lead mine since Roman times. It was reopened for barium spars in 1845, and was last working in 1914.

There may be considerable reserves of witherite below the present 60-fm. level in the rich section between Coldlawdean and the Low Engine Shaft. The rich horizon, however, of the Whin Sill and the Scar Limestone occurs, probably, at too great a depth to be exploited. There is no evidence along the course of the Fallowfield Vein that there is any further extension of the spar which is likely to prove of commercial importance.

2.—Durham.

General Account.

The county of Durham is an important producer of barytes and witherite, the chief centres (*see* Plate IV.) being in Upper Teesdale and in the immediate vicinity of Durham itself. Smaller quantities of spar have been obtained from the neighbourhood of Wolsingham, in Lower Weardale. The Teesdale mines are remotely situated, the chief ones, Cow Green, being 9 miles from the nearest railway; and that a profitable working can be carried on under such conditions is evidence of the abundance and quality of the spar.

The distribution of the minerals calls for some remark. In Teesdale, barytes occurs as a gangue in lead-bearing veins, traversing the Carboniferous Limestone Series. It is noteworthy that in Weardale, a valley immediately to the north, the gangue of the veins in similar strata consists of fluorspar. Clearly the

nature of the vein contents is not wholly determined by the type of the country-rock, for the mineralising agents were of deep-seated origin, and there has been no leaching from the adjacent strata. This contention is supported by the fact that barytes is met with in the heart of the county, not in the Carboniferous Limestone, but in the Coal Measures at Ushaw Moor and at New Brancepeth, while around Wolsingham it invariably occurs in the Millstone Grit.

These occurrences show that the distribution of barytes in Durham is confined to certain districts, or to a province of mineralisation, and not to particular geological formations.

Details of Collieries.

New Brancepeth Colliery.

Messrs. Cochrane and Company, Ltd., Middlesbrough.

The colliery shafts are on the south side of the River Deerness, immediately west of Ushaw Moor Station (N.E.R.), and about 3 miles west of Durham.

Maps.—One-inch New Series Ordnance, 26; Old Series Geological, 103 N.W.; six-inch Durham, 26 N.E., P.

The barytes occurs in a fissure-vein along the course of a fault trending practically east and west, and with a downthrow south of 120 ft. The country-rock consists of the Middle Coal Measures, and from the westerly limit of the New Brancepeth workings, south of Cookhouse Farm, the vein has been followed for upwards of a mile eastwards to the neighbourhood of Aldin Grange.

Westwards it would appear to be the same as the Tow Law Vein, now being worked at Ushaw Moor Collieries (p. 13). The width of the vein averages from 4 to 6 ft., but is apt to change abruptly, the vein sometimes pinching out altogether, while a few yards further on it may increase to a width of 16 ft.

Above the Harvey or Beaumont Coal, the vein is lost. Downwards it has been followed at least 10 fms. below the Brockwell Coal, which lies about 30 fms. below the Harvey Coal, without any sign of deterioration, either in thickness or in quality.

The barytes, with occasional patches of witherite, is in vein form only, and there are no "flats." Apart from variable amounts of country-rock the barytes is remarkably pure, closely grown, and milk-white. It is frequently in granular masses several feet across. With the exception of witherite, accessory minerals are practically absent;* in this respect New Brancepeth and Ushaw Moor contrast strongly with other barytes veins in the North of England, where quartz, calcite, galena, and chalybite are almost invariably present. Witherite forms less than 1 per

* The few found, some of them of exceedingly rare types, have been described by L. J. Spencer, *Mineralogical Magazine*, Vol. xv, 1910, p. 303

cent. of the total spar production. As a rule it occurs in nodular masses with a scaly surface; these are white or pale greenish-yellow in colour, are translucent, and have a radiate internal structure. The mineral is found on the walls of the vein in irregular pockets up to 3 ft. across; it is quite pure, and usually free from barytes.

Contact with different beds of coal, sandstone, or other rocks has no effect on the contents of the vein. The reverse does not hold, for the coals in the neighbourhood of the vein are so impregnated with barytes along their joint-planes as to be valueless.

Between the several levels there are communication shafts, down which the barytes is shot to the lowest working, from which it is taken along the colliery haulage road to the main haulage shaft. All the spar has to be blasted out. The workings extend laterally for about half a mile, and vertically for 40 or 50 fms. They have not been carried above the Harvey Coal, where the vein is lost, but their present limit in depth is only dependent on the coal-workings, which make a convenient means of access and drainage. The water does not exceed 50 gallons per minute at the most, but, when the vein happens to transgress a coal seam, gas is sometimes troublesome.

At the pit head, after the spar has been washed, useless material is removed by hand-picking, and the witherite taken out, the chief demand being for the raw lump form. The barytes is then crushed and passed through a small Luhrig washer and a vanner, which reject the fragments of country-rock, and the cleaned barytes is then dried and milled to a fine powder. The ultimate product is classified in the following seven grades, according to colour: "Lily White," "Best White," "No. 1 White," "W.W.," "A.C.," "A.," "B." Very little raw lump-barytes, which averages 92 per cent. of barium sulphate, is sold. The residual sludges from the jigs run to waste.

The vein was discovered about 1895 when driving through the 20-fm. fault in search of coal.* It has been worked continuously since 1900. The average output to 1918 amounted to 5,000 tons per annum. As the spar, which is accessible from the present coal-workings has been largely mined, little barytes is at present being produced. In 1907 the output attained 10,297 tons. The vein shows no sign of change at the lowest depth reached, and there seems no reason why it should not continue much farther down; laterally also the workings could be extended, but trials have not yet been made.

Ushaw Moor Collieries.

Messrs: Pease and Partners, Ltd., Darlington.

The colliery shafts are close by Flass Hall, in the valley of the River Deerness, 4 miles west of Durham.

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* *See* R. Peel, *The Colliery Manager and Journal of Mining Engineering*, Vol. xvi, 1900, pp. 56–58.

Maps.—One-inch New Series Ordnance, 26; Old Series Geological, 103 N.W.; six-inch Durham, 26 N.E., N.W., P.

Barytes and witherite occur in two prominent fissure veins in the Lower and Middle Coal Measures. These veins, known respectively as the Tow Law and South Busty, both appear to be branches of the main vein worked at the adjoining colliery of New Brancepeth.

The coal seams worked are the Harvey, Busty, Brockwell, and Ballarat. The barytes veins are persistent throughout the whole thickness of the measures worked, and appear to be quite unaffected by the country-rock, whether it be coal, shale, or sandstone.

The Tow Law Vein, generally referred to as the Main Vein, may be looked upon as the westerly continuation of the New Brancepeth Vein. It has been followed in a south-westerly direction from a point 300 yds. due south of Hare Holme Farm, past Biggins Farm, to near Hill House. There are, however, indications of the vein on the surface at Standalone Farm, and in the western end of Weather Hill Wood Plantation, on Wooley Hill, the barytes vein is exposed at the surface. It was also met with in the underground workings of the Esh Winning Collieries, which are a little over a mile south-west of Ushaw Moor Colliery. The total distance over which the Tow Law Vein can be followed from Aldin Grange to Wooley Hill is $4\frac{1}{2}$ miles. The South Busty Vein runs in a north-west direction, and extends from a point 500 yds. due east of Cockhouse Farm, Ushaw Moor, to join the Tow Law Vein about 300 yds. due north of Ushaw Moor railway station.

The spars are confined to the veins and there are no "flats." The sides of the vein consist of a fine black mud, with a high barytes content, the mineral being in a remarkably minute state. This substance has been collected and utilised for numerous purposes. It has been tried with success to replace the fine-grained material at present employed to check coal-dust explosions in mines.

The Tow Law Vein follows the course of a prominent fault with a downthrow to the south of 40 fms. The vein hades slightly south, at an angle of 9° from the vertical. Its average width is from 6 to 10 ft., but in places it ranges up to 22 ft. The vein is filled almost exclusively with barytes, except for occasional masses of country-rock and pockets of witherite. It has been worked in a vertical direction for only 50 ft., but as it is present in all the levels, it will be worked when the coals are being mined.

The South Busty Vein, which has so far been worked over a horizontal distance of 396 ft., follows the course of a prominent fault in the Coal Measures, with a throw to the south of about 14 fms. The vein has an average width of 4 ft., but in places it swells out to 16 ft., while occasionally it pinches to less than

2 ft. in width. It is essentially a witherite vein, consisting in many places of extremely pure greenish-yellow crystalline spar, without any other minerals. Frequently it is much mixed with barytes. The richest workings are in the neighbourhood of the Busty Coal, where many rich pockets have been met with, and finely crystalline masses obtained. In a vertical direction the South Busty Vein has been worked from the Brockwell Coal (the lowest level) to a total height of 132 ft., or 36 ft. above the Busty Coal levels. In neither vertical direction does the vein show any sign of depreciation.

The barytes was first worked about nine years ago, but the output was small until 1921. In the latter months of 1920 the average weekly output was 100 tons, but in the spring of 1921 the daily output was about 100 tons, or 500 tons a week. All the products are sold on the "unit" system. A branch of the North Eastern Railway adjoins the colliery, where the spars are directly loaded.

The higher grade witherite needs only hand-picking, and is then sent away. Of this grade about 30 tons a week are being produced. The remainder is crushed and passed through a small washing plant and vanner to reject the fragments of country-rock. The major portion is sold as small lump, and the remainder in the form of a coarse powder. The finished product is employed in the paint and lithopone industry.

Occurrences of Barytes in other Collieries of Durham.

Although New Brancepeth and Ushaw Moor are the only collieries in which barytes and witherite have been worked, the presence of barium compounds has been detected in other localities.

At Croxdale Colliery, 3 miles south of Durham, a vein of barytes, 2 ft. wide, occurred along the course of a prominent east and west fault in the Busty and the Brockwell Coal workings.

At Lumley Colliery, 4 miles north of Durham, similar occurrences of barytes have been observed, while at Ryhope Colliery, near Durham, barytes has been met with in the workings in the Maudlin Coal.* In the Durham and Newcastle districts the water in the mines has been known to deposit barium sulphate in the pipes.†

Details of Mines.

Knitsley Fell Mine.

Messrs. J. Cameron, Swan & Co., Ltd., 4, St. Nicholas Buildings, Newcastle-on-Tyne.

The mine is on Knitsley Fell, about 2,000 yds. due west of Harperley Station (N.E.R.), and about 2½ miles south-east of Wolsingham.

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* A fine specimen from this colliery is exhibited at the Museum of Practical Geology, London.

† F. Clowes, *Proc. Roy. Soc.*, London, Vol. xliv, 1889, pp. 368, 369.

Maps.—One-inch New Series Ordnance, 26; Old Series Geological, 103 N.W.; six-inch Durham, 33 N.W., P.

The barytes occurs in a nearly north-and-south vein, traversing the sandstones and shales of the Lower Coal Measures and the Millstone Grit. The workings are alongside Howleel Lane (which crosses the open moorland) at a point 900 yds. west of Shipley Moss Farm, and close to the gannister mines, worked by the Knitsley Fell Gannister Company. The workings, which are all opencast, extend over a horizontal distance of 500 yds. from this point in a northerly direction into the western end of Black Bank Plantation. The vein is very irregular, and consists of a series of lenses of fairly solid barytes. Its average width is about 4 ft. By means of open workings it has been followed to a depth of 23 ft., but owing to its irregularity no mining has been done. The barytes was hand-picked to remove country-rock before being sent away.

The Knitsley Fell mines were worked intermittently in the 19th century, and were closed in 1872. Between 1885 and 1890 the extensive dumps were exploited, and about 400 tons of barytes sold. In 1917 the workings were reopened, and about 400 tons of spar were raised before the mines were taken over by the present management. Little work is now being done, owing to the lack of demand for barytes. An aerial ropeway, 2,300 yds. long, from the summit of Knitsley Fell, 900 ft. above O.D., connects the workings with Harperley Station (N.E.R.).

Shull Rigg Mine.

Weardale Barytes and Mining Co., Ltd., Bishop Auckland, Durham.

This mine is on the western slopes of Knitsley Fell, $2\frac{1}{2}$ miles south-east of Wolsingham.

Maps.—One-inch New Series Ordnance, 26; Old Series Geological, 103 N.W.; six-inch Durham, 33 N.W., P.

Two E.N.E. and W.S.W. veins, about 15 yds. apart, consisting almost exclusively of white crystalline barytes, occur here in the Millstone Grit. They have been followed in a north-easterly direction for a distance of about 100 yds. both by opencast workings, and by a day-level along the course of the principal vein. At this point they coalesce, and by means of old opencast workings can be traced for another 300 yds. They vary in width from 2 to 4 ft.

A trial has been made along the course of another vein 200 yds. north-west of the mine, in Knitsley Plantation.

The barytes was not subjected to any special treatment before being sent away.

An aerial ropeway, 400 yds. long, connects the workings with a central stage alongside the Wolsingham-Bedburn main road, from which the material is loaded into carts, and conveyed a

distance of about 2 miles over a hilly but good mountain road to Wolsingham station (N.E.R.).

Black Hill Top Mine.

Weardale Barytes and Mining Company, Ltd., Bishop Auckland, Durham.

The mine is about 1½ miles west of Hamsterley, and 4 miles south of Wolsingham.

Maps.—One-inch New Series Ordnance, 26; Old Series Geological, 103 N.W.; six-inch Durham, 33 S.W., P.

The mine workings, which are 400 yds. south-east of Black Hill Top Farm, near Hamsterley, and 600 yds. south-west of Bedburn Hall, are along the course of a N.N.W.–S.S.E. vein in the sandstones and shales of the Lower Coal Measures and Millstone Grit. At 300 yds. south of the present workings the Whin Sill pierces these rocks in an E.N.E. and W.S.W. direction.

The vein, which has been followed by shallow opencast workings over a horizontal distance of 300 yds., has an average width of 3 ft., and consists mainly of white crystalline barytes. The mineral disappeared at depth.

These workings are closed.

Other Workings of Barytes in the Wolsingham District.

Maps.—One-inch New Series Ordnance, 26; Old Series Geological, 103 N.W.; six-inch Durham, 18 S.W.; 25 S.E., S.W.; 32 N.E., S.E.; and 33 N.W., S.W.

At Burnhill, Wolsingham Park (six-inch map Durham, 18 S.W., P.), 4½ miles north of Wolsingham, and 1 mile south-east of Waskerley, barytes has been worked in veins in the Millstone Grit. Between 1885 and 1888 about 100 tons were sent away. It was obtained only in shallow opencast workings, the spar disappearing at a small depth. A few years ago an unsuccessful effort was made to reopen these mines.

About 1¼ miles east of Wolsingham, trials for barytes were made near Bowlees Farm (six-inch map Durham, 25 S.W., P.) in 1918 for the Weardale Barytes and Mining Company. Barytes is abundant along the course of a N.N.E. and S.S.W. vein, in the Carboniferous Limestone Series, which can be followed for a distance of a mile past Low Wiserley to near Crowsfield. Due south of Crowsfield, in North Wiserley Plantation, there are numerous old workings apparently along the course of the same vein. These yielded upwards of 100 tons of barytes about 30 years ago.

At Baal Hill, 1,000 yds. south-west of Tow Law station (N.E.R.) and 2½ miles east of Wolsingham (six-inch map Durham, 25 S.W., S.E., P.), trials have been made for barytes along the course of a prominent N.N.E. and S.S.W. vein in the Millstone Grit. These

were attended with small success, but, further south, workings along the course of the same vein in Black Band Plant Wood, to the north-east of Knitsley Hill, yielded, about 20 years ago, considerable quantities of high grade barytes. The old dumps contain much good quality spar.

There are old workings for barytes at Sunnyside Allotment, 1,000 yds. due south of Sunnyside Lead Mines, and about 1½ miles south-west of Wolsingham station (six-inch map Durham, 32 N.E., P). The barytes occurs in east and west veins in the Carboniferous Limestone Series, the workings being about the horizon of the Fell Top Limestone. No work has been done for the past 20 years.

At a point 2 miles due south of Wolsingham station lie the old workings for lead-ore and barytes known as Harthope Hill (six-inch map Durham, 33 N.W., P.). They occur along the course of east and west veins in the Millstone Grit on both sides of Harthope Beck, and about 400 yds. north-east, and 700 yds. due north respectively of St. John's Hall. The veins vary in width up to 2 ft., and consist almost entirely of white crystalline barytes. There was a small, regular output of barytes until about 30 years ago.

At Cabin Hill, on Pikestone Moor, 2½ miles south of Wolsingham station (six-inch map Durham, 33 S.W., P.), barytes has been obtained from a N.W. and S.E. vein in the Millstone Grit. The open-cast workings, now disused, are about a mile west of Hoppyland Hall.

In North Grain Beck valley, 3½ miles south of Wolsingham (six-inch Durham, 32 S.E., P.) good quality barytes was mined 20 years ago. The old workings are situated 600 yds. due north of Ayhope Shield Farm, close by the confluence of North Grain and South Grain Becks, and are along the course of numerous east and west veins in the Carboniferous Limestone Series. Owing to difficulties of transport no effort has been made to reopen the workings.

Grasshill Common.

Trial-workings on the Teesdale-Weardale watershed, 2½ miles south of Wearhead.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Durham, 30 N.W., N.E., P.

Several prominent N.E. and S.W. veins in the Carboniferous Limestone Series have been worked for lead-ore and carry considerable quantities of barytes. From north to south these are: the North Langton Head Vein, the South Langton Head Vein, the Grasshill Vein, the Black Lead Vein, and the Coldberry Vein. Trials were made for barytes in the past few years along the course of the two latter veins.

In the Coldberry Vein, trials have been made along the eastern side of the Grasshill-Ireshope road at a point 100 yards

north of the watershed near Coldberry High Level. The vein is here 4 feet wide, and in association with it a flat, or horizontal stringer, of barytes penetrates the Great Limestone for a few yards.

In a small surface-trial this flat was about 2 feet thick, and the debris thrown out from it includes much barytes, mostly milk-white, but some water-clear, and with good crystal faces. Pink or discoloured spar is not common; no quartz was seen, but there was an occasional fragment of fluorspar, while the country-rock appears to have been iron-stained limestone. Similar flats of barytes occur in the immediate vicinity, one being exposed by the hill-road.

On the south side of the watershed, 300 yards north-east of Grasshill House, further trials for barytes were made in 1919 in the old lead-veins at Highfield Hushes. The spar was reported to be 3 ft. thick; the spoil heaps show good milk-white barytes, the transparent variety being rare, and no quartz was seen. The country-rock is the Great Limestone, shattered and iron-stained. No witherite was observed at either of the above localities.

Cow Green Mines.

The Hedworth Barium Company, Ltd., 1, St. Nicholas Buildings, Newcastle-on-Tyne.

These mines consist of a group of scattered workings on Harwood Fell close to the River Tees and about 9 miles W.N.W. of Middleton-in-Teesdale.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Durham, 30 S.W., P.

The barytes is obtained from old lead-workings known as Dubby Sike, East Cow Green, West Cow Green, Greenearth or Greenhurth, Isabella, Willy Hole, and the Rods mines, which have been opened along vertical veins in the Yoredale Beds, and in the underlying Melmerby Scar Limestone. The veins are in close proximity to the Whin Sill and are most productive in the limestones.

The East and West Cow Green Veins trend nearly north and south; the Dubby Sike, Isabella, Long Band End, and Rods Veins all run approximately N.E. and S.W., while some nearly east and west veins also carry barytes.

Barytes is the principal constituent, but galena, in relatively small quantity, occurs in all, generally concentrated towards the centre of the veins. Witherite is found sparsely in some; quartz, calcite, and blende also occur in varying amounts.

The barytes is in places much iron-stained and intergrown with country-rock, but in others is pure and white. In some of the veins that have been worked to a considerable depth a remarkably pure, glassy white barytes has been obtained.

The most easterly vein, the East Cow Green or Teesdale Vein, has been worked to a considerable extent, originally for

lead-ore, above the level of the water. It consists of two parallel veins each about a yard wide normally, but where they come together, there is a total width of productive ground which may be as much as 6 yds. A shaft has been sunk to a depth of 16 fms. at East Cow Green Shop, alongside the main road, and from this the vein has been followed north for upwards of three-quarters of a mile. Little water was encountered, a 3-in. windmill pump being sufficient to remove it. The vein is intersected by many east and west veins, and becomes exceptionally productive at the points of intersection. The old dumps have proved very rich, notably where the Isabella and Teesdale veins intersect.

About 600 yds. south of East Cow Green there are some old workings in the Rods Vein, and other parallel N.E. and S.W. veins in Slapstone Sike, and near the River Tees. A small shaft was sunk in the Rods Vein, and showed some 4 ft. of pure white barytes. An adit has since been driven along the vein to meet this shaft. The Rods Vein, formerly worked for lead-ore, has yielded good quality barytes.

At West Cow Green, the West Cow Green, the Long Band End, and some smaller veins, run respectively north and south, and N.E. and S.W., and are now being worked. At their intersection, 70 yds. due north of the main road at West Cow Green, a shaft has been sunk, to a depth of 24 fms., and both veins are being worked to the north and the south.

The Long Band End Vein consists of a succession of lenses or swells in which barytes is predominant, while in the narrower parts galena is more abundant. These lenses occur wherever the vein is crossed by east and west lodes. They have an average length of 300 ft. and an average width of 10 ft. Between them the vein averages 4 ft. in width.

At West Cow Green 550 yds. north-east of Weelhead Fold, and on the Long Band End Vein, a borehole was carried to a depth of 250 ft., piercing the Whin Sill at a depth of 180 ft. Throughout the bore in the Whin Sill, the vein consisted exclusively of witherite.

The Long Band End Vein has been followed for a distance of 400 yds. from Weelhead House alongside the River Tees to the rising ground at Long Band, and its upper part worked over for barytes. At Weelhead it is about a yard wide. At Long Band it varies from 2 to 8 ft. wide.

The Isabella workings lie at the head of Easter Sike and to the north of the East Cow Green workings. The vein courses N.E. and S.W. and, in marked contrast to the Long Band End Vein, preserves a uniform width of from 4 to 5 ft. The recent workings along it extend for upwards of 500 yds. It consists predominantly of barytes.

The Willy Hole zinc mines, which lie 1½ miles north of the Cow Green mines, have recently been reopened to work barytes. The principal vein, trending east and west, has an average width

of 4 to 6 ft., and contains mainly barytes and zinc-blende. While the higher levels carry little barytes, it is the predominant mineral in the lowest levels. Several smaller veins ranging up to a yard in width have also been worked. The northerly continuations of the north and south veins at Cow Green are met with, and have been opened out for barytes.

The Dubby Sike mine, which has been worked to a considerable extent for barytes, lies about a mile due west of the Cow Green shafts.

A prominent N.E. and S.W. vein has been traced from the western side of Harwood Beck, across the River Tees at Low Crag Pool for a distance of about 3 miles. It is intersected by several smaller veins running approximately N.N.W. and S.S.E. and known from north to south as Annie's Vein, Cross Vein South, and New South End Vein. They are all in the Yoredale Beds, and at their outcrop the first two are near, and the third lies in the Whin Sill. The veins are most productive in limestone, notably the thick Melmerby Scar Limestone.

The Dubby Sike Vein ranges from 4 to 8 ft. in width, and has been worked over a distance of about 120 yds. Barytes is its predominant constituent, galena being absent. In the deeper workings excellent quality barytes was met with.

The Dubby Sike mine was started for barytes in 1890. So far only the upper 12 to 14 ft. of the vein have been worked.

The Greenearth, or Greenhurth, mine and shaft, is 1,200 yds. further along the road from the Dubby Sike mine. It is 2 miles distant from Cow Green. Greenearth is an old lead mine, closed 15 years ago. Witherite occurs, though only where the veins traverse the Whin Sill, and cerussite is plentiful.

The Greenearth Vein runs east and west, and is from 9 to 10 ft. wide, although in places it thins down to 6 in. In addition to barytes it contains fair quantities of galena, for which it was principally worked. From a level, 6 to 8 fms. deep, small quantities of barytes were mined, but the work was stopped owing to the remote situation of the mine, and also on account of water trouble. At Greenearth several of the N.N.W. and S.S.E. veins of Dubby Sike have been met with, and found to carry barytes.

Except for the removal of galena by jigging, the barytes at Cow Green mines is not subjected to any special treatment. It is sent to Newcastle, and used in the preparation of barium compounds, especially baryta or barium oxide.

All the barytes from the several mines is conveyed along tramways which converge upon a central dump at Cow Rake, close by Hopkin's level, East Cow Green. From thence it is conveyed by aerial ropeway a distance of 2 miles to Langdon Beck Hill, alongside the Alston-Middleton main road. From this point it is taken in Foden lorries to Middleton-in-Teesdale station (N.E.R.), a distance of $7\frac{1}{2}$ miles.

Formerly all the Cow Green mines were worked for lead-ore. They were reopened for barytes about 25 years ago, and at first

about 200 tons were obtained annually. Since 1899 the annual output of barytes has averaged 2,000 to 3,000 tons. Within the past few years it has been about 5,000 tons.

The output of lead-ore in 1912 was 66 tons, but the average has been about 30 tons per annum.

The reserves of barytes at the Cow Green mines must be considerable. The work has been mainly on or near the outcrop of the veins, several of which have been traced 2 or 3 miles and have yielded large quantities of barytes. In depth they are not only highly productive, but the barytes is of good quality.

Bands Mine.

Messrs. Temple and Towards, Harwood, Middleton-in-Teesdale.

The mine is on Langdon Fell, 9¼ miles W.N.W. of Middleton-in-Teesdale.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Durham, 30 N.E., S.E., P.

This mine was originally worked on the surface for iron-ore and at depth for galena. The alternating limestones, shales and sandstones of the Carboniferous Limestone Series which crop out in a N.W. and S.E. direction, are crossed by the Bands Vein, a prominent fault, by which the beds are only slightly displaced.

The lode, 1 to 3 ft. wide, has been followed for a distance of 1,000 yds. in a north-easterly direction from a point immediately north of Lingy Hall across the Alston-Middleton-in-Teesdale main road to Knotted Scar, where it is hidden by thick peat.

There is practically no barytes in the vein itself, but the crystalline variety occurs in the form of flats in the shales between the limestones. Generally the "hazel," or sandstone, forms the floor of the flat, and shale, the roof. The barytes has been principally obtained in large opencast workings which have been carried to a depth of 20 ft. An old day-level enters the vein, but has not yet been used to mine the barytes at depth.

The present workings are in flats, above the horizon of the Scar Limestone, 500 yds. north-east of the Alston-Middleton-in-Teesdale main road.

The barytes is frequently iron-stained, but except for crushing, and removal of the country-rock by hand-picking, receives no special treatment. All the material is sent away as "small lump" of half-an-inch grade, very little "large lump" spar being obtained.

The present output averages about 30 tons a month.

Ettersgill Mines.

R. W. Raine, Esq., J.P., Middleton-in-Teesdale.

The mines lie about 7 miles north-west of Middleton-in-Teesdale and on the north side of the Middleton-Alston road.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Durham, 30 S.E., P.; 31 S.W., Ms.

At Tinkler's Meadow, 1,000 yds. due east of the hotel at Langdon Beck Head, and 7½ miles north-west of Middleton-in-Teesdale, a prominent N.E. and S.W. vein in the Carboniferous Limestone Series was worked for lead-ore. At High Hurth Edge the old workings are in the Great Limestone, in which are numerous "flats" of lead-ore and barytes. There are many old levels in these workings, and in 1919 these were partially re-opened, and some "small-lump" barytes obtained. Barytes is abundant in many of the surrounding dumps.

At Ettersgill Beck, 2,000 yds. east of the above, there are similar old workings, also in the Great Limestone, in which barytes is the predominant spar constituent. These workings are being reopened for barytes at old shafts and levels alongside Beck Head House, and at Gill Shop.

Widdy Bank Fell.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Durham, 38 N.W., P.

At Widdy Bank Fell, alongside the River Tees, and about 8 miles west of Middleton-in-Teesdale, the thick Melmerby Scar Limestone is underlain by the Whin Sill, and in the limestone several N.E and S.W. veins were formerly worked for lead-ore. The main workings are at a point 500 yds. south-east of the River Tees at Black Brae Nook, and extend in a north-easterly direction for about 600 yds. White crystalline barytes is abundant in all the old spoil heaps, but has not hitherto been worked.

Flushiemere Mine.

Messrs. William and W. Lee, Newbiggin, Middleton-in-Teesdale.

The mine lies at about 1,480 ft. above O.D., on Newbiggin Common, on the eastern slope of Flushiemere Beck.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Durham, 31 S.W., Ms.

Barytes, with a smaller quantity of witherite, is obtained principally from the Flushiemere, or Flushiemea, Vein, which follows a fault running N.N.W. and S.S.E., and also from flats associated with it. Many smaller veins run parallel to it, while others trend east and west. A series of N.E. and S.W. veins have also been worked, the most important being the Chesterhead, the New Streak and the Broadley Hill Veins.

The main vein has been extensively worked for lead-ore, and many of the old dumps which are rich in barytes have been worked over for that mineral.

The Flushiemere Vein, which has an average width of 12 ft., is most productive in the Great Limestone. It is connected with three series of flats, which have proved highly productive both of lead-ore and barytes, and especially the Middle Flat.

About 12 years ago the Broadley Hill Vein was worked for barytes, and at that time about 10 tons of witherite were obtained from a level 450 yds. higher up Flushiemere Beck.

From the eastern side of Flushiemere Beck and close to Flushiemere Shop, a level has been driven north-east almost at right angles to the Flushiemere Vein. It intersects, and then more or less follows, the course of the vein in a N.N.W. direction. The vein was worked for more than a mile, solely for lead-ore, but the greatest quantities were obtained in the associated flats referred to above. The depth of the lead workings is 100 ft.

The barytes and witherite have so far only been got from the extensive series of old lead-workings, and partly from the stowage, in which the barytes remains intact.

The barytes varies from a pure white to a highly coloured and ferruginous spar, and most of it is subjected to washing and jigging. The principal impurities include laminae and pockets of galena, which are removed as far as practicable, together with ferruginous and other colouring matter. Witherite occurs in small quantities locally.

There appears to be no difficulty with water at present. The higher levels, now being worked for barytes, drain away into older workings at a much lower level. In wet and stormy weather the water may rise 2 ft. or so, but it quickly subsides. No pumping is done.

The crude barytes is raked backwards and forwards on a perforated table under a constant current of water, and much ferruginous and other impurity thereby removed. Masses rich in galena are set aside, and impure lumps are broken up for further washing. The small lump barytes is sent to market after the calcite and other lighter minerals have been separated out by a hand jig.

The barytes appears to be principally used in the paint industry.

Flushiemere is an old mine, and was extensively worked more than a hundred years ago. It was first opened out for the mining of barytes in 1904. The average annual output up to 1908 was 70 tons. In 1908, 226 tons were extracted, while for the past 12 years the annual output has averaged 400 tons.

Only the dumps have been picked over, and the most accessible levels worked, but there is evidence of considerable reserves of barytes in the veins beyond the limits reached by the old miners.

Snaisgill Mine.

R. W. Raine, Esq., J.P., Middleton-in-Teesdale, Durham.

The mine is close to the confluence of Snaisgill Sike and Hudshope Beck, and about a mile due north of Middleton-in-Teesdale.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E., six-inch Durham, 39 N.E., S.E., Ms.

North of Middleton-in-Teesdale, several prominent north-east and south-west veins traverse the limestones, sandstones, and shales of the Carboniferous Limestone Series. The principal of these, from north to south, are the Snaisgill Vein, the Holme Head Vein, and the Tinkers Vein. These carry some barytes, but the flats associated with them are the principal source of that mineral. The veins are richest in the Great Limestone, where in Teesdale there are three main series of flats. In the higher beds fluorspar replaces barytes as the principal spar constituent of the veins. In the beds underlying and overlying the Great Limestone the veins also pinch considerably and there are no flats. At the Snaisgill mine, the lowest flat was the richest in barytes and also in galena.

The barytes obtained at Snaisgill was whiter and purer than that at the majority of mines in Teesdale.

The veins and flats have been worked from an adit level on the slopes of Snaisgill. In the main or lower flat, the workings extend to 28 fms. from the surface, at which depth the permanent water-level is reached.

The barytes was hand-picked. The best lump was sold as such : the remainder was crushed, jigged, and washed, and sent to market in the powdered state.

The chief uses were in the paint industry.

Snaisgill is an old lead mine, reopened as a barytes mine in 1887. Up to 1894, when it was closed, 1,700 tons of barytes were obtained, the greater portion consisting of high grade lump barytes. This had only to be hand-picked before being sent away.

When the lower flat in the Great Limestone had been followed as far as the water-level, mining operations were suspended, but barytes of excellent quality remains in the mine.

3.—Cumberland.

General Account.

Cumberland is not a large producer of barytes. The deposits fall into two classes :—the chief producers, in which barytes is the only commercial mineral; and those in which barytes is a subsidiary product to ores of lead and zinc. The first class includes the deposits of Ruthwaite and Potts Ghyll. At Ruthwaite the vein is large but deteriorates in depth owing to the presence of quartz; the barytes, moreover, is pink. At Potts Ghyll, though the deposit is somewhat irregular, the barytes is of the fair grade white variety and could be much improved by bleaching. In the second class, the barytes is frequently of high grade; but in lodes carrying blende dressing is difficult and some kind of flotation is necessary to get clean concentrates. The Elmore plant at Force Crag is of interest in this particular, though its capacity is small.

Around Alston, on the eastern side of the county, both barytes and witherite are frequently the predominant spar constituents of the numerous veins which traverse the Carboniferous Limestone Series. In recent years they have been worked at the Hartside, Park, and Nentsbury Mines (Plate IV.), but the difficulties of transport have hitherto prevented any important developments.

Details of Mines.

Ruthwaite Mine.

Concrete Materials, Ltd., 19, South John St., Liverpool.

Situated at Ruthwaite, 1¼ miles south of Ireby.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 N.W., Ms.

Barytes was first mined here some 40 or 50 years ago; since then work has been carried on intermittently. The present Ruthwaite Mine was formerly known as John Peel Mine, while the Ruthwaite Mine of the earlier days is now spoken of as "Blacklock's." These properties are about 300 yds. apart and worked the same vein. "Blacklock's" was given up about 1915 and soon afterwards the old John Peel Mine was reopened under the name of Ruthwaite Mine.

Barytes occurs here in a north-west and south-east vein in a fault, which, towards the north-west, throws down the Carboniferous Limestone against the Borrowdale Volcanic Series, but lies entirely in the latter in the neighbourhood of Ruthwaite. The vein hades to the south-west at about 10° from the vertical. The foot-wall consists largely of hard barytes, about 6 in. thick, mixed with a certain amount of sandy country-rock, and is often lined with clay. The hanging-wall is less regular. The average width of the vein is about 8 ft.; real "nips" are unknown, but in places the vein swells from 4 ft. to 16 ft. Crop workings average 10 to 12 ft. wide, all in barytes, but in depth the vein is more constricted and, unfortunately, quartz and rock make their appearance in the lower levels.

The barytes is pale pink, generally clean and rather tender. Calcite and lead-ores are unknown, but occasional traces of malachite are seen.

When crop workings had removed the easily accessible material the vein was attacked from shafts; the most important at the present mine being "Gurney's." This is 90 ft. deep with levels at 50, 70, and 90 ft. "Blacklock's" Shaft, now disused, situated on slightly lower ground to the south-east, was 40 ft. deep and connected with the 50-ft. level from Gurney's Shaft. Between these two lies the old shaft at Dolly Byre, and also a ladder-way.

Above the 70-ft. level, which extends 420 ft. to the south-east and 200 ft. to the north-west of Gurney's Shaft, the vein is practically exhausted, while considerable stoping has been done above the 90-ft. level.

Material is raised through the shaft by a steam crane, and dumped on a shoot where it is hand-picked to remove rock deads and inferior grades mixed with quartz. All the barytes is now sent away without further treatment, though a grinding-plant was at one time in use.

Potts Ghyll Mine.

Potts Ghyll Barytes Mining Company, 46, Queen Victoria St., London, E.C.4.

Situated 2 miles south of Caldbeck.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 N.E., Ms.

Some work was done here about 50 years ago, but the mine lay abandoned until 1915 when it was taken up by members of the present company. It has been closed since September 1920, but is by no means exhausted.

The barytes occurs in two veins, about 50 yds. apart, running roughly east and west through the ashes and lavas of the Borrowdale Series of the Caldbeck Fells. These veins have received no definite names, but will be described in the following account as the North and South Veins.

The barytes, though frequently much ironstained, is fair grade white; it is sometimes mixed with quartz which is the only other vein mineral.

The North Vein, which has received most attention, hades southwards at from 20° to 40° from the vertical. The foot-wall is usually better defined than the hanging-wall. The deposit appears to consist of a number of lenses or bunches of barytes occurring lengthwise in the vein, but in different positions with regard to the country-rock, and either in the middle, or on one or other of the walls. These lenses are separated by rock-breccia frequently heavily charged with quartz. Some of the "horses" are several yards in thickness. This irregularity, especially when a hanging-wall lens overlaps a foot-wall bunch, has led to confusion on the part of the workmen both in mining and nomenclature.

No. 1, the lowest level, has been driven east on the vein for about 90 yds. and ends in barren ground. It strikes some good grade lenses up to 5 ft. in thickness which have been worked up to near the No. 3 level, where they die out.

Westward it has been cut about 30 yds. and a good pocket worked through the intervening stope of No. 2, into No. 3 level about 25 ft. above the adit.

The lode in No. 3 level east is poor and contains much quartz, but improves west of the cross-cut adit. At about 150 ft. along No. 3 level west, a string is given off to the south-west, showing up to 15 in. of good barytes, but at present it is untouched. At 235 ft. west of the cross-cut, the vein swells to a bunch o good barytes 10 ft. thick; but about 30 ft. further west it thins down to 2 ft. and less, and is mixed with quartz.

At 200 ft. west, a 25-ft. rise on the foot-wall side was put up to No. 5 level, where a mass of barytes 5 ft. thick was struck, but much of it had already been extracted by the old company. This portion is spoken of as " the vein behind the main lode," but is in reality a lens on the country-rock with a false hanging wall formed by a horse. Followed westward in No. 5 level the vein was extremely pockety and at the far end, about 50 yds. beyond the western limit of No. 3, is in rock with strings of quartz. At this point a cross-cut was driven south for about 20 yards, which after cutting a quartz string, touched, but did not penetrate, a rock-breccia, containing much quartz and occasional patches of barytes. This is believed to be the " foot-wall " of another lens of barytes.

The South Vein also is subject to sudden nips, but does not seem quite so irregular as to mineral distribution as the North Vein. It underlies south at about 20° from the vertical and contains some fair-grade white barytes. In the main adit of the mine, or No. 1 cross-cut, it was met with about 50 yds. south of the main lode. At this point it is a foot wide but increases to 4 ft. at higher levels. In a small drift at the surface it is as much as 8 ft. wide and is all good barytes, but in about 50 yds. it dwindles to 2 ft. of barytes mixed with quartz. As in the North Vein, quartz is more abundant in the nips and under the foot-wall.

The North Vein has been worked from levels Nos. 1 to 5 through a vertical height of about 50 ft., thin cranches having been left between the levels. No. 1 and No. 3 levels are connected with the surface by cross-cuts and form tramming roads. No. 3 cross-cut is 40 yds. in length; No. 1 is about double that distance to the lode, but is continued south to cut the South Vein and 10 yds. of the country-rock beyond. No. 1 cross-cut and levels form the adit below which no mining has been done.

At the mine-mouth the material is washed and roughly sorted over a grid. It is then carted to Caldbeck—the first mile of road being exceedingly rough. At Caldbeck it is crushed and jigged. After drying on a kiln floor it is milled through two pairs of horizontal stones. As no bleaching is done the resultant powder is rather greyish yellow in colour.

The reserves in this mine are probably large, but the sporadic occurrence of the mineral bunches and the long haul to rail render working expensive. Crushing and jigging at the mine would obviate the carrying of mixed deads to Caldbeck, while grading and bleaching of the better-class material would improve the quality of the finished product.

Gilcrux Mine.

T. Dand, Esq., Old Domain Saw Mills, Aspatria.

Situated in Rose Gill, $\frac{3}{4}$ mile S.S.W. of Bullgill Station (Maryport and Carlisle Ry.).

Maps.—One-inch New Series Ordnance, 22; Old Series Geological, 101 N.W.; six-inch Cumberland, 45 N.E., Ms.

Barytes here occurs in two fault veins, one at the junction of Rose Gill and Green Gill and the other (Green Gill Vein) crossing the latter gill some 200 yds. to the north-east. The former is a fault of considerable magnitude. It ranges from near Tallentire on the south, from a little west of north to north-west at the foot of Rose Gill, where it meets a fault trending west by south. These faults limit the coal workings to the west and north by bringing up pre-Coal-Measure shales, sandstones and limestones. The Green Gill Vein, ranging north-west is in a fault, probably of small throw, confined to the pre-Coal-Measure strata.

The barytes in both veins is, on the whole, of the fair quality white variety, though somewhat ironstained, together with some of darker colour mixed with stone, and some pink spar. Barytes is the only mineral present though rock in places constitutes part of the vein-filling. Neither vein exceeds three feet in thickness, and both appear subject to sudden nips. This fact may be due to the thin-bedded nature of the strata, which introduces a different type of country-rock in a few yards run on the vein, and here, as elsewhere, shales often prove " unkind."

Workings have been on a small scale, and so far have produced about 25 tons of crude barytes as the result of considerable expenditure. Where tried in the angle of Rose and Green Gills the big fault showed 2 ft. of barytes for a few yards in length, but the mineral nipped out at both ends. In depth the vein was tested to 18 ft., mostly in good barytes, but as the vein lies below stream-level, water came in faster than it could be removed by hand labour. On the south bank of Rose Gill, where the ground is higher, the vein is pinched to a few inches between Coal Measure sandstones and shales, and shales belonging to an older series, which were previously mapped as Millstone Grit, but possibly belong to the Carboniferous Limestone Series.

The Green Gill Vein, first discovered in a trial pit about 50 years ago, has been reopened by a 29-ft. shaft between the stream and the end of the old lane a few yards to the north. The southern wall consisted of sandstone, limestone and shale, similar to the beds exposed lower down the gill, while the northern wall, which is reported as bad and hanging, was of blue shale. Barytes occurred up to 2 ft. in thickness, but work was stopped by flooding. To the south-east three other trial pits were sunk on the probable course of the vein. One, immediately across or south of the stream from the first shaft, was 40 ft. deep and with cross-cuts of a few feet located the lode, which here contains much rock. Two others situated about 140 and 200 yds. to the south-east of the first shaft were 42 ft. and 24 ft. deep respectively; neither succeeded in bottoming the glacial drift which evidently thickens rapidly in this direction. Work on this vein was then abandoned.

Force Crag Mine.

Braithwaite Mines, Ltd., Force Crag, Braithwaite, Keswick.

Situated at the head of Coledale, 2½ miles S.W. of Braithwaite village.

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Cumberland, 63 S.E., P.

This mine* has had a somewhat chequered history partly attributable to the difficulties in the past of separating barytes from blende, and to the predominance of those two minerals over galena. It was opened about 1830, and the Nos. 1, 2 and 3 levels were then driven, but as barytes was unsaleable little attention was paid to it. After a short interval the mine was re-opened for barytes, and as that mineral was found to be more plentiful on the higher ground, the lower levels were abandoned and the Nos. 4 and 5 levels commenced. A tramway was constructed to the village and mills erected for bleaching and grinding, but the undertaking proved unremunerative, and the mine was abandoned in 1880.

In 1906 the mine was taken up for lead- and zinc-ores, the lower levels re-opened and a dressing plant erected. Owing to the difficulties of dressing blende and barytes the mine was abandoned in 1909, during which year 35 tons of barytes were produced. The Coledale Mining Syndicate began work in 1912, and continued it until 1915. They were responsible for the installation of the Elmore plant, but were hampered by inadequate crushing machinery. The present company was formed about the year 1916.

The Force Crag Vein is believed to extend from the head of Coledale westward to the foot of Crummock Water, a distance of nearly 3 miles; but with the exception of a small trial near Lanthwaite Gate, at the western end, it has been worked only at Force Crag.

The vein courses a little north of east through the Skiddaw Slate Series, and generally hades northward at 75° from the horizontal, though at times it is practically vertical.

The vein-filling, apart from blende, galena and barytes, consists mainly of brecciated rock, with thin irregular strings of quartz. Of the other minerals psilomelane occurs in the higher part of the vein, and a little dolomite, along with some chalybite and pyrites, is of general distribution. Cerussite and stolzite (tungstate of lead) are also reported, and small crystals of fluorspar were found recently.

The proportion of barytes to ores is about 3 : 1, and blende is about 10 times as common as galena.

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* *See* Special Reports on the Mineral Resources of Great Britain, Vol. xxii, "The Lead and Zinc Ores of the Lake District" (*Mem. Geol. Surv.*), 1921, pp. 20–23: and J. Postlethwaite, "Mines and Mining in the Lake District," 3rd Edition, 1913, p. 105.

The width varies from an average of 5 ft. up to 20 ft., and the walls are usually well defined. In places, as in the middle portion of No. 1 level, the lode splits into two veins, from 2 to 4 ft. wide, separated by a barren tract or "horse" 12 to 15 ft. across. Small branches or veinlets are given off at different points, but they carry ores only near the vein.

On the top of the mountain the vein consists mainly of barytes with some psilomelane, and very little galena and blende. In depth blende with some galena becomes more abundant. In No. 3 level and the stopes above it, they form the chief ores, the barytes occurring only in small patches on the walls or occasionally running irregularly though the vein. In the lowest worked or No. 1 level barytes comes on again. In a stope just east of the cross-cut to this level the vein is 15 to 20 ft. wide and has, in addition to ribs in the middle of the vein, lenses 2 to 3 yds. long and 6 to 8 in. thick of good white barytes on the walls. Where the "horse" appears the veins carry in places 6 in. to 3 ft. of solid barytes. In April, 1921, sinking on the hanging-wall was in progress from No. 1 level, about 240 ft. west of the adit cross-cut. At a depth of 20 ft. a trial stope has been opened out showing good grade barytes from 2 to 4 ft. in thickness.

The vein has been opened up by a system of levels, the highest, No. 5, being about 400 ft. above No. 1. Extensive screes at the outcrop on the hill-side have necessitated the use of cross-cuts driven from the south, from which levels Nos. 1, 2 and 3 proceed. No. 1 cross-cut is about 120 yds. long, the others being a half and a third of that length. No. 3 level is 15 fms. above No. 2, and the latter 24 fms. above No. 1. Nos. 4 and 5 levels, driven directly on the vein, are disused. No. 1 level has been driven west about 180 fms., but the vein there is said to be disturbed and may be faulted. A cross-cut commenced some years ago with the object of cutting the Force Crag Vein 120 ft. below No. 1 level has not been completed, and mining, with the exception of the sinking referred to above, is confined to the ground between No. 1 and No. 3 levels. Much of this ground is exhausted.

No. 1 level and cross-cut form the main drain of the mine, and no pumps are required except for sumps.

Some of the lump barytes is picked out in the mine, whilst the rest of the material is trammed to a picking-grate above the crushing-plant. The ores are subjected to the ordinary processes common to lead-mining and subsequently, in order to separate barytes from blende, the Elmore vacuum flotation process, which separates practically pure blende is used. The gangue from the Elmore plant is then cleaned up on a long Buss table, and yields a medium grade barytes sand.

Power is supplied by a Pelton wheel operated by water from a reservoir at the head of the beck, 600 ft. above the level of the mine building.

Brundholme Mine (including Blencathra).

Brundholme and Newland Mines, Keswick.

Situated in Glenderaterra Valley (between Skiddaw and Saddleback) a little south of Roughten Gill.*

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Cumberland, 56 S.E., P.

The earliest mining† that was carried on, in about 1820, was near Roughten Gill. Levels were driven northwards on two veins and a shaft sunk below adit level, but the workings were then abandoned.

About 1850 a shaft was sunk to a depth of 20 or 25 fms. on the eastern side of the stream, about half a mile south of Roughten Gill, but lack of capital led to the mine, known as "Blencathra" being abandoned, though some good ore was obtained. The vein worked lies 12 fms. east of the shaft. Some distance to the north it is said‡ to be broken. To the south it has not been proved. Short levels were driven lower down the valley to attempt to cut the western vein, but were abandoned before attaining their object.

In 1872 work was recommenced about 300 yds. south of Roughten Gill and the shaft now used as a pumping shaft was sunk to 30 fms., with levels north and south at 20 and 30 fms. from the surface, but the mine was soon closed again.

After an interval of many years the mine was reopened, the levels begun in 1872 were pushed out, chiefly to the south, and a run of ore was found about 40 fms. south of the shaft. When this was exhausted the mine again closed down, though periodic trials were made. Recently it has been reopened by the Brundholme Co. They have sunk a shaft to the "rise" worked by the old company. It is 33 fms. south of the pump shaft, and in April, 1921, was standing at 5 fms. below the 30-fm. level.

There are two main veins, one running a little east of north from the foot of Lonscale Crags to Roughten Gill, and the other a little west of north and coursing southwards from Sinen Gill. These two intersect about 100 yds. south of the junction of Roughten Gill with the main stream; and to the south, near the old Blencathra mine where they are about 120 yds. apart, are united by a small cross-vein bearing E.N.E. and W.S.W.

These veins, which may be seen in the beck and its tributaries, traverse Skiddaw Slates, in the aureole around the Skiddaw Granite, and pass into unaltered strata on the south.

The veins are filled with rock fragments and quartz, with variable amounts of barytes, galena, copper pyrites, and some cerussite, malachite, and chrysocolla. The northern parts

* Not the Roughtongill of the Caldbeck Fells.

† J. Postlethwaite, "Mines and Mining in the Lake District," 3rd edition, 1913, pp. 101–103.

‡ "Northern Part of the English Lake District" (*Mem. Geol. Surv.*), 1876, p. 52.

of the veins between Sinen and Roughten Gills are said to have yielded mainly copper pyrites, but farther south galena, accompanied by barytes, prevails. The latter mineral is white and apparently of good quality though somewhat ironstained in the upper workings, and occasionally mixed with quartz.

The vein worked at the Brundholme Mine is that coursing a little east of north; it averages 4 ft. in breadth, but occasionally swells up to 10 or 12 ft. From the surface down to the 20-fm. level, it is practically vertical but below that hades east at 1 in 15. The foot-wall is usually well defined, but the hanging-wall is more irregular and often lined with very hard quartz, whereas over the rest of the vein the quartz is generally soft. With the exception of an eight inch string towards the hanging-wall between the two shafts, barytes is commonly found in patches and irregular masses lying between lenticles of coarsely crystalline galena. Such copper pyrites as occurs is frequently found towards the middle of the vein, and is closely associated with quartz.

The vein is said to have held good only for 10 or 12 fms. on each side of the south shaft. Over the rest of the ground, sops though frequently of promising appearance have proved to be small.

Access to the vein is gained by two shafts 33 fms. apart; the northern, or old shaft, is used for pumping, and the southern, new shaft, for winding and as a ladder-way for the men. The former has a sump in the floor of the 30-fm. level, while the latter has been sunk 5 fms. below that level and will be deepened to explore lower ground. The two main levels at 20 and 30 fms. have been driven 27 and 24 fms., respectively, north from the pumping shaft, and 8 and 45 fms. south from the winding shaft.

Power for pumping is supplied by a water-wheel. Winding is to be carried out by compressed-air developed by means of a water-turbine assisted in dry seasons by an oil engine. At present an inadequate supply of water for the turbine is brought by a leat from the junction of Roughten Gill and the main stream. There is no dressing beyond hand-picking, and all the material is sent away as "crude." The total output of the Brundholme company amounts to 60 or 70 tons of barytes, about 20 tons of galena, and a few tons of sugary quartz per annum.

Threlkeld Mine.

Threlkeld Lead Mines, Ltd., Thornthwaite, Keswick.

Situated half a mile N.N.E. of Threlkeld village.

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Cumberland, 56 S.E., P.

The mine has been worked intermittently for many years for lead- and zinc-ores, and as such is more fully described

elsewhere.* The " lead and zinc " lodes, known as the Woodend and Gategill Veins, traverse Skiddaw Slates; both hade west and at the south end of the mine course N.N.W., but farther north the former swings round to N. 10° E., and displaces the latter 20 fms. Neither of these veins in the main workings contains barytes, but in the adit level on the Woodend Vein, about half a mile from the mine entrance, a small vein carrying barytes was met with in a short cross-cut east. The barytes is of good quality, white, and practically free from metallic ores, but is not in sufficient quantity to be worth working.

Carl Side Vein.

(Idle.)

Situated half a mile north of Millbeck hamlet, about 2 miles N.N.W. of Keswick.

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Cumberland, 56 S.W., P.

This vein traverses Skiddaw Slates from east to west and hades southwards at 30° from the vertical. It appears to be one of several offshoots from the main vein which runs north-west along Carl Side.

The east and west vein is visible in an old trial-hole at the foot of the crags. It is about 4 ft. in width, and, apart from a few thin ribs of rock and quartz, consists of barytes of fair quality, though somewhat ironstained. Galena is said to have occurred in small bunches and pockets, and this trial-hole, with others which have fallen in, was dug in search of that mineral.

The hanging-wall is firm and heavily charged with quartz; the foot-wall is softer, and near it barytes alternates with ribs of quartz. The country-rock is a hard blue shale of the Skiddaw Series, and is traversed by numerous strings of quartz.

The workings appear to have ceased in the prospecting stage.

Roughtengill Mine

(Idle.)

Situated 3½ miles S.S.W. of Caldbeck and 7 miles N.N.E. of Keswick.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 S.E., Ms.

The old " stope and feather " workings† in this mine down to a depth of 20 fms. were made before the use of gunpowder

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* Special Reports on the Mineral Resources of Great Britain, Vol. xxii, " Lead and Zinc Ores of the Lake District " (*Mem. Geol. Surv.*), 1921 pp. 11–14.

† J. Postlethwaite, " Mines and Mining in the Lake District," 3rd edition, 1913, p. 129.

was known. In the time of Queen Elizabeth copper-ores were raised and sent to Keswick for smelting, but until the beginning of the 19th century operations were on a small scale. From 1835 to 1875 large quantities of lead- and copper-ores were raised, and the mine worked to a depth of 90 fms. In 1878 it was regarded as exhausted* and was closed down.

From 1888 to 1894 a few men were employed by the Cleator Iron Ore Co. for the purpose of raising barytes and umber. From 1889 to 1892 the yearly output of barytes amounted to 166, 137, 77 and 91 tons respectively. For the succeeding two years the output of Roughtengill is included with other mines owned by the same company.

Roughtengill has long been famous for the variety of its minerals, including ores of lead, zinc, and copper, with their coloured alteration products, in addition to gangue minerals, a characteristic which may be due to the diversity of the country-rocks. Skiddaw Slates occur on the west and south-west; Eycott (Borrowdale) Series on the north; and felsite and gabbro on the south and east. This rock complex is traversed by numerous faults, some of which carry ores. The two main lodes range from W.S.W. to S.W. between Frozen Fell and Sandbeds Mine, a distance of from 3 to 4 miles. These lodes approach within 200 yds. of each other at Roughtengill, where they are known as the North and South Lodes, and were most productive when in contact with the gabbro. The veins contain similar ores, but the South Lode at one place swells up to a width of 30 ft. and there contains much calcite. This great " bunch " is probably connected with the two parallel veins, 11 fms. apart, mentioned by Postlethwaite;† while the cross-course of that author is the fault along the eastern Thief Gill. The vein-filling is chiefly broken rock and quartz, the only other gangue of importance being calcite, which, though rare in other parts of the Lake District, is locally abundant at Roughtengill. In addition to the ores of lead, zinc and copper, barytes of good grade occurs. Though a considerable amount of work has been done on the other lode, the South Lode has been more extensively wrought, ores having been obtained over a length of about three-quarters of a mile. The more important workings were the 30-, 60-, and 90-fm. levels, which were approached by cross-cuts from the north. A shaft was sunk to 20 fms. below the 90-fm. or adit level. The entrances to these workings are now closed.‡

The dumps are extensive, but appear to have been so thoroughly overhauled that they are valueless from a commercial standpoint, though they still contain many interesting mineral specimens.

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* *Ibid.*, p. 130.

† *Ibid.*, p. 129.

‡ A more detailed description of the mining and geology of Roughtengill is given in Special Reports of the Mineral Resources of Great Britain, Vol. xxii, " Lead and Zinc Ores of the Lake District " (*Mem. Geol. Surv.*), 1921, pp. 36–39.

Redgill Mine.

(Idle.)

Situated half a mile W.N.W. of Roughtengill.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 N.E., S.E., Ms.

This mine* has been wrought in conjunction with Roughtengill, and also by various small companies, but information relating to them is vague.

The country-rock of the Redgill mining-field consists of lavas and ashes of the Borrowdale Series of Caldbeck. There are three main veins, two trending between N.W. and S.E., and N.N.W. and S.S.E., and one from N.N.E. to S.S.W. The last is a fault of considerable throw, mineralised over part of its course. The vein-filling, in addition to barytes, consists of quartz and rock carrying lead- and copper-ores. The good white and slightly pink varieties of barytes appear to have been more abundant in the southern N.W. and S.E. vein, especially in the upper parts of the lode.

All the lodes have been tried, but the southern vein has received most attention, though never on a large scale. Apart from some trial cross-cuts, work ceased about 50 years ago.

The dumps are small, and consist mainly of quartz and "rock deads."

Drygill Mine

(Idle.)

Situated $3\frac{1}{2}$ miles south of Caldbeck, and a quarter of a mile S.W. of Driggith Mine.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 S.E., Ms.

This mine† was worked on a small scale about the middle of last century for lead-ores. About the close of its career in 1876 a little blende was raised. There is no record of the working of barytes, and the small amount of this mineral present in the dumps probably represents all that was taken out. Quartz appears to be the chief vein stuff. In addition to the ores already mentioned some psilomelane, encrusting other minerals, is present, and is common in the dumps.

Driggith Mine.

(Idle.)

Situated at the head of the Driggith Beck, a tributary of Carrock Beck, and about $3\frac{1}{4}$ miles south of Caldbeck.

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* For detailed description, *see* Special Reports of the Mineral Resources of Great Britain, Vol. xxii, "The Lead and Zinc Ores of the Lake District" (*Mem. Geol. Surv.*), 1921, pp. 39–41.

† Special Reports on the Mineral Resources of Great Britain, Vol. xxii, "The Lead and Zinc Ores of the Lake District" (*Mem. Geol. Surv.*), 1921, pp. 41–43.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 47 N.E.; 48 N.W., Ms.

This mine* was opened in 1700, and wrought by shallow shafts and day levels to a depth of 25 fms. It was more vigorously operated by various companies in the earlier half of last century, but closed down about 1870. The only ores raised were those of lead. After lying idle for many years the mine was taken up by the Caldbeck Mining Company from about 1904 to 1908. Since then it has been abandoned. Ores of lead, zinc and copper were obtained and some barytes, but figures are not available as to the output of the last mineral.

The main vein courses north-east, and was also wrought at the Roughtengill and the Sandbed Mines (pp. 33, 37). It is believed to be a mineralised fault between a lava and an altered ash in the Eycott, or Borrowdale Volcanic, Series.

The vein is said to average 4 ft. in width, though swelling at some places to 8 ft., and nipped to a few inches at others. Along the extensive crop-workings the vein hades slightly to the north-west. In places it is 8 ft. wide, with a 6-inch rib of barytes on the hanging-wall, followed by quartz, impure psilomelane, and pyromorphite, with irregular ribs of barytes on the foot-wall. In depth it is said to have carried quartz and barytes on the walls, with blende, galena, and copper-ores in the middle, the blende predominating. A local miner states that in the deeper workings a vein of practically solid barytes, averaging 2 ft. in thickness, lies from 20 to 40 yds. to the N.W. of the main lode, from which it may be an offshoot. Apart from crop-workings the lode has been worked from cross-cuts and levels spoken of locally as the 30-, 60- and 90-fm. levels, though the altitudes are somewhat less. As the mine was wrought in conjunction with the Sandbed Mine the length of vein worked may be taken at about half a mile, but it was probably not all extracted. Driggith was worked to 90 fms., but, according to Postlethwaite,† the bulk of the ground excavated was above the 60-fm. level, the 90-fm. level being less productive.

Most of the plant has been removed, but lump barytes seems to have been picked out before the ores were treated. The dumps, mainly of quartz, are fairly extensive and contain some good-class barytes, though sometimes it is mixed with quartz.

The obstacles to working this mine appear to be (1) insufficiency of water for dressing; a "leat" from Dry Gill seems to have been the chief supply; (2) the association of blende and barytes, which, in the absence of cheap hand-picking, requires a flotation plant for the separation of the minerals.

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* Special Reports on the Mineral Resources of Great Britain, Vol. xxii, "The Lead and Zinc Ores of the Lake District" (*Mem. Geol. Surv.*), 1921, pp. 43–45.

† "Mines and Mining in the Lake District," 3rd edition, 1913, p. 130.

Sandbed Mine.

(*Idle.*)

Situated to the north of Driggith Mine, one mile S.W. of Woodhall and three miles south of Caldbeck.

Maps.—One-inch New Series Ordnance, 23; Old Series Geological, 101 N.E.; six-inch Cumberland, 48 N.W., Ms.

At this mine the same N.E. and S.W. vein as that at Driggith was worked for lead-ore up to about 50 years ago, since then it has been abandoned.

There are extensive dumps of quartz and "rock deads," with a fair quantity of high class white barytes, apparently from ribs 6 to 8 in. thick, and some blende similar to that of Driggith. There is a little galena, and some traces of pyromorphite, copper pyrites and malachite, with crusts of psilomelane.

The mine suffered the same difficulties in working as Driggith. Water was brought in a leat over a mile in length from Carrock Beck.

Bannerdale Mine.

(*Idle.*)

Situated under Bannerdale Crags, north-east of Saddleback.

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Cumberland, 57 N.W., Ms.

The vein runs east and west through the spotted schist of the Skiddaw Series, and hades south at 20° from the vertical. The country-rock near the vein dips in the same direction at about 50°, or 40° from the vertical.

The vein is from 4 to 6 ft. in thickness, but barytes comprises of this only a small amount. In the upper level there is a string of barytes about 8 in. thick near the hanging-wall, and another string, about 6 in. thick, of slightly pink barytes on the same wall near the entrance; while a little occurs also on the foot-wall.

The barytes varies from white, with a little iron-staining, to pale pink, and appears to be of fair quality, but there is only a little of it. In addition to barytes the lode contains strings of quartz. The metalliferous minerals are blende and galena, with a little iron pyrites and traces of copper-ore. Graphite* is recorded as having been worked for making grate-polish and Bannerdale pencils. All that can be seen now is a little irony carbonaceous matter adhering to the sides of the lode, while some of the spotted schist is polished.

The vein appears to have been worked only under the crags, where there are two levels. The lower, or adit, is full of water; the upper can be entered for a short distance, but is in a ruinous condition. The dumps are very small, but contain a fair proportion of barytes, and some blende.

* "The Geology of the Northern Part of the English Lake District" (*Mem. Geol. Surv.*), 1876, p. 67.

The levels are in the steep face of the crags and are not easy of access. The valley is waterlogged and boggy, and there is no road up to the mine beyond the Glenderamackin.

Hartside Mine.

(Idle.)

The Hedworth Barium Company, Ltd., 1, St. Nicholas Buildings, Newcastle-on-Tyne.

Hartside mine is situated on the western slopes of Hartside Height, 6½ miles west of Alston.

Maps.—One-inch New Series Ordnance, 24; Old Series Geological, 102 N.W.; six-inch Cumberland, 41 N.W., Ms.

To the west and south of Hartside Height there are several veins generally trending in a N.E. and S.W. direction in the Carboniferous Limestone Series, which invariably contain barytes as the principal spar constituent.

The most westerly working is on Harescough Fell, where a N.E. and S.W. vein has been followed from Green Band to Loo Gill, along the eastern side of Rowton Beck. Open workings at a point 700 yards due north of the Old Busk limekiln have yielded considerable quantities of high-grade barytes within the past few years. The vein, in the Great Limestone, has an average width of 13 feet, and contains very clean slightly pink barytes, with traces of lead-ore.

A second vein, 450 yds. east of this, also contains abundant barytes, but little work has been done on it. Good quality barytes is abundant on the old dumps. This vein follows the course of a prominent fault which can be traced in a south-westerly direction, and crosses Loo Gill, where it is joined by Ricker Gill.

The third vein, which runs E.N.E. and W.S.W., follows almost entirely the course of Loo Gill, and has been worked at several points. These workings extend from alongside the old coal workings, 750 yds. north-west of Hartside Height to a point 170 yds. south-west of the Old Busk limekiln. In some prominent crags of fine-grained calcareous sandstone on the north bank of the stream, 850 yds. W. 25° N. of Hartside Height, the vein appears to consist of a broad shatter belt, 30 yds. wide, in which rock fragments are cemented with milk-white barytes. There is no solid vein at this point, the spar being only in small clusters and pockets, rarely a foot across. No quartz or other accessory minerals were observed, but the barytes, although apparently of excellent quality, is far too mixed with fragments of country-rock to be workable.

A fourth vein runs practically parallel with the above lode and at a distance of 200 yds. south of it. Its width is 6 ft., and barytes has been obtained by open-cast workings at several points along its course.

Other barytes-bearing lodes occur at Hartside Cross, and follow a N.E. and S.W. direction. The principal one crosses the Alston-Penrith main road, 700 yds. west of the fifth milestone from Alston. It has proved most productive in the Great Limestone immediately south of Hartside Cross, though the barytes from here is much iron-stained. This vein has been worked on the surface for iron-ore.

On the whole, the veins were found to be most productive in the limestones, but more especially so when followed to the south and west, where lower beds of the Carboniferous Limestone Series crop out, and also in the neighbourhood of the Whin Sill which here occurs just below the bottom of the Scar Limestone.

The barytes from the workings is all conveyed by means of tram lines to a central dump near Hartside Cross. There it is hand-picked to remove the country-rock. There is no other treatment, and all the sorted material is carted to Alston Station (N.E.R.) a distance of over 6 miles, over a good mountain road.

The mine was opened in 1915, and has since been working intermittently.

Park Mines.

The Hedworth Barium Company, Ltd., 1, St. Nicholas Buildings, Newcastle-on-Tyne.

The Park Mines are situate on the western side of the South Tyne, a quarter of a mile north-west of Alston.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Cumberland, 33 S.E., Ms.

There are two prominent N.E. and S.W. lodes, the Park Grove, and the Park Grove Sun Veins, which have been followed for a distance of about a mile from Hall-hill plantation, alongside the River South Tyne, to Black House plantation on Park Fell. In Hall-hill plantation these two veins run together. In the past few years, a level was commenced close to Mark Close House with the intention of reopening the old workings. Superficially the veins have yielded fairly good quality iron-ore. Barytes occurs in the veins, and is reported to occur also in extensive flats in the Scar Limestone. These were formerly worked for lead-ore.

The Park Mines are old lead mines, worked in the 19th century by the Park Mining Company, but closed in 1872. The old workings have largely fallen in. They were reopened by Mr. Borlase of Harwood, on behalf of the Hedworth Barium Company in 1917, and considerable quantities of fairly high-grade barytes have been obtained from them. Except for hand-picking, the spar was not subjected to any special treatment, but forwarded by road to Alston Station (N.E.R.), less than a mile distant from the mine.

Blagill Mine.

(Idle.)

Vieille Montagne Zinc Company, Nenthead, Alston.

The mine is 1½ miles E.N.E. of Alston.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Cumberland, 34 N.W., P.

There are several lead-bearing veins trending in an east and west direction, which have been worked, notably the Lough Slitt and First Rake, or Blagill, Veins. The latter vein has an average width of from 9 to 10 ft., and yields a low-grade witherite mixed with stone and a little lead-ore. The workings extend from the Firestone Sills down to the Four-Fathom Limestone, but the veins were most productive in the Great Limestone, where numerous flats yielded large pockets of witherite.

In the latter part of the 19th century these mines were being worked for lead-ore and witherite. From 1880 up to 1896 Blagill was a small but regular producer of witherite. Except in 1887 when 812 tons of witherite were mined, the annual output never rose to more than 200 tons, and latterly fell as low as six tons. In 1880 and 1882 a few tons of barytes were also obtained.

Nentsbury Mine.

Vieille Montagne Zinc Company, Nenthead, Alston

Nentsbury Mine is in the Nent Valley, three miles E.S.E. of Alston.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Cumberland, 34 S.E., S.W., P.

At Nentsbury a series of prominent N.E. and S.W. lead- and zinc-bearing veins are crossed at right angles by a N.W. and S.E. series. Among the former the most important are the High Raise, North Green and Nentsbury Haggs Veins, and of the latter, the Well Gill and Carrs Veins.

Barytes and witherite are mainly found in the High Raise Vein, which has been followed in a north-easterly direction from High Nentsbury for a distance of 1,400 yds. both by underground and surface workings. An old east and west cross-cut 350 yds. long enters the lower workings in Brown Gill to the north of Nentsbury. The vein, which is up to 10 ft. wide, follows a line of fault with a downthrow of 10 ft. to the north-west, and is in the Upper Yoredale beds.

All the underground workings are just above the valley bottom at Nentsbury, the lowest main level at the furthest point being 1,218 feet O.D. The water is therefore almost wholly removed by adit draining. Barytes and witherite are frequently abundant, together with quartz, calcite, galena, and blende; the last two being the chief products of the mine.

The main body of barytes occurs 500 yds. north-east of where the Brown Gill cross-cut entered the workings in the High Raise Vein. From this point for about 400 yds. in a north-easterly direction it was essentially a barytes vein, with an average width of 4 ft. It is from this portion of the lode that the main quantity of barytes has been obtained. Still further to the north-east the barytes diminishes, and the lode again becomes payable for lead-ore.

At 250 yds. beyond the county boundary, the vein is crossed by an east-and-west fault with a downthrow to the north of 20 ft. The present working face is 140 yds. north-east of this point and in the Quarry Hazel. Here the vein contains much barytes, witherite and calcite, mixed with a little blende and galena. It is proposed to make a rise to reach the Great Limestone, in which the lode will probably be richer.

In the "hushes" along the fell top good quality barytes is abundant in the dumps.

The intimate growth of the ore and spar at Nentsbury rendered hand-picking for lump-spar an impossibility. The galena was separated in jigs, and the residue sent away as impure witherite; the blende being removed subsequently and returned to the smelter at Nenthead.

Nentsbury cannot be regarded as an important source of barium compounds; the difficulty of separating both sulphate and carbonate is too great for any extensive production. In the case of the witherite, a mineral whose sale depends largely on its purity, the lime content gave great trouble. The mine is of interest as a barium producer in a country where vein-gangues mostly consist of fluorspar, calcite and quartz.

Other Occurrences of Barytes and Witherite in the Alston District.

A series of veins coursing north-eastwards and bearing lead-ores occurs in the Great Limestone at Scarberry Hill, 3 miles south-west of Alston (six-inch map Cumberland, 41 N.E., Ms.). There are numerous dumps around the old workings in which good quality barytes is a predominant constituent.

At Crag Green, near Garrigill, and $2\frac{1}{2}$ miles south of Alston (six-inch map Cumberland, 42 N.W., Ms.), there are several disused lead-mines which have yielded small quantities of barytes. There are numerous N.E. and S.W. veins in the Carboniferous Limestone Series, and the workings extend from the Scar Limestone up to the Great Limestone. Barytes is abundant on the extensive dumps.

At Wellhope, in the Allendale country, on the borders of Cumberland and Durham, and 7 miles E.S.E. of Alston (six-inch maps Durham, 22 N.E.; N.W., P.), there are some disused lead-mines which have yielded lead-ore together with small quantities of barytes and witherite. The ores occur in a series of N.E. and S.W. veins in the Carboniferous Limestone Series, and the

workings extend from the horizon of the Single Post Limestone to the Great Limestone. In the Scar, Five-Yard, and Great Limestone flats occur in association with the veins. In the upper workings above the Great Limestone, barytes occurs as caulk forming radiating masses in the vein, while in and below the Great Limestone the white crystalline variety is more usually met with.

4.—Westmorland.

General Account.

Westmorland has been for over 30 years a producer of barytes. In the western part of the county, included in the Lake District, the deposits are of slight commercial importance and unworked, but to the east, in the Carboniferous Limestone of the Pennine Chain, the veins are numerous and wrought extensively. The Brough district (Plate IV.) can be regarded as part of a large mineral province, which includes the Lunehead area of Yorkshire (pp. 51–54), and the important Upper Teesdale deposits of County Durham (pp. 18-24), and altogether forms one of the richest barytes regions in this country. The reserves appear to be ample, for many of the smaller veins are untouched, the working mines are relatively shallow and the deposits show no sign of deterioration in depth. But this mining district, like many others, is handicapped by difficulties of transport.

North of Brough, the newly developed field of Long Fell, which has good reserves, and the area around Scordale, produce high grade spar. The deposits at Scordale are adjacent to the Whin Sill and some of the "flats" are reported to contain broken fragments of that rock. The deposition of barytes therefore must have been subsequent to the igneous intrusion.

Most of the deposits occur along planes of dislocation, but those of Longfell appear to be in fissure veins, unaccompanied by faulting, or along joints enlarged by solution. They are comparable to the "flats" of Scordale. The caverns at Lunehead are of interest here though that mine is in Yorkshire. They are associated with the Cavern Veins in the Great Limestone and when found were filled with red plastic clay containing lead-ore towards the bottom. The walls carry wisps of galena and barytes. That these caverns are due to solution is beyond question, the red clay being the insoluble residue of the limestone.

Details of Mines.

Cabbish Mine.

J. G. Reynoldson, Esq., Brough, near Appleby, Westmorland.

The mine is situated at Peniston Green, three miles east of Brough, and north of the main road from Brough to Bowes.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Westmorland, 17 S.W., Ord.

This mine was formerly worked for lead-ore but was reopened for barytes about 1906. Since then it has been worked until recently, when it was closed owing to trade depression. It is not exhausted and will probably be reopened when prospects improve.

There are 800 yds. of arched adit between the mine entrance at Peniston Green House and the shafts. The workings, both in the Cabbish Vein and in the Old Man's Vein, are ancient. The latter vein is 4 ft. wide and joins the main vein near the sump. The present holders of the mine have worked north-east of the shaft; they commenced by robbing the barytes left by the lead miners, and since have broken some new ground. There are several fault-veins in this area traversing the shales, sandstones and limestones of the Yoredale Series. Some have been worked for barytes; others though known to carry that mineral are as yet untried. Of the former the most important is the Cabbish Vein and its branches, which trend approximately N.E. and S.W. Of the latter the chief are the Shot Vein, which is 2½ ft. wide, and lies 200 yds. south-east of and parallel to the Cabbish Vein, and the Augills Vein, which trends N.W. by S.E., from west of Dummah Head, past the Blue Bell Inn at North Stainmore, to Dowgill, a distance of 2,500 yds.

The Cabbish Vein for part of its course is a single vein, but about 900 yds. along the adit from the mine mouth it joins the Old Man's Vein, lying to the south of it, and then splits into two branches. Of these, that on the south is known as the Parlour Vein, and the one on the north as the Main or Cabbish Vein. Not far from the bifurcation of the veins, another lode, known as the Clay Vein, joins the Main Vein; it also carries barytes and has been worked back for about 70 yds. to the south-east.

About 1,000 yds. along the level from the adit mouth, both the Parlour Vein and Main Vein terminate against shale which is brought in by a cross-fault. It is believed that this fault throws down the measures to the north-east. It forms the present limit of the workings, but when the mine is reopened will be driven through from the lower level of the Main Vein.

The Cabbish or Main Vein above adit level was from 5 to 10 ft. wide. It was most productive in the Great Limestone, but became constricted and barren as it passed into the cover of sandstones and shales. The Parlour Vein, from 3 to 5 ft. wide, also produced some good barytes, and a little was obtained from "lead" workings in the Old Man's Vein. All these, with the exception of arches or cranches, are exhausted above adit level between the adit mouth and the cross-fault.

Near the split, at the junction of the Clay Vein with the main lode, and also at the far end of the Parlour Vein, small sumps have been made, but the principal workings below adit level are by the cross-fault at the far end of the Main Vein. Here a blind shaft has been sunk to a depth of 25 ft. and barytes stoped back to the south-east over a length of 50 yds. At the bottom

the vein averages 3 ft. of barytes enclosed in walls of solid limestone and shows no signs of deterioration.

The adit-level forms the main drain and the haulage-way of the mine, both water and barytes being raised to it by an engine at the top of the blind shaft referred to above.

The mineral is hand-picked at the surface; some of the lower grades are sent away to the market for the lithopone trade, while better qualities are jigged, and carted 3 miles to Brough, to be ground. The processes are similar to those employed at Lunehead (p. 53). Brough is 2½ miles from Warcop Station (N.E.R.).

The output of Cabbish Mine, from the reopening in 1906 to 1914, amounted to 16,000 tons of lump barytes and 300 tons of ground* barytes.

The following figures represent the output in tons of barytes from 31st December 1914 to 31st December 1920. During that period about seven tons of dressed lead-ore was also obtained :—

	Ground.	Crude.
1915	672	61
1916	748	93
1917	844	111
1918	722	80
1919	744	266
1920	564	122

Long Fell

Long Fell Barytes, Ltd., Warcop, near Appleby.

Situated on the crest and western face of Long Fell, about 6 miles east of Appleby.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Westmorland, 16 N.W., Ms.

Unlike most of the mines in this area, which are abandoned lead mines re-worked for barytes, Long Fell is a new venture. Although barytes had long been known to occur, work was not commenced until about 1914.

Several veins trend north-east across the Melmerby or Great Scar Limestone. They are all fissure veins, apparently unaccompanied by faulting, and are practically vertical.

The junction between the vein-mineral and the country-rock is sharp, but the walls of the veins are frequently irregular, causing alternate nips and bunches. Occasionally tiny strings are given off from the vein.

Apart from some clay, "muck," and occasional ribs of limestone, the vein-filling consists entirely of barytes. No calcite, quartz, fluorspar or lead- and zinc-ores have been met with. Some green stains suggest the former presence of small specks of copper-ores.

The veins occupy a belt of country about 300 yds. wide and are described under A to E from north to south.

* Apparently no milling was done in connection with this mine until 1913.

Vein A has been followed on the limestone pavement at the fell top for three-quarters of a mile. It has been worked only at the crop, where it varies in thickness from a few inches at the nips to 6 or 8 ft. in the swells. It contains good crystals of barytes.

Vein B has been worked by open stopes on the fell top for about 400 yds., and shows barytes all the way, but a level below the crest, after cutting through a length of several feet of barytes, entered soft clay or "douk." The south wall consists of good limestone ; the north wall was never located. At about 210 ft. from the entrance, a 40-ft. shaft cuts the level and meets a good vein of barytes up to 6 or 8 ft. thick, and the level continues in this run for a further 70 ft. The far end shows 2 ft. 3 in. of somewhat iron-stained barytes between a south cheek of limestone and a north one of "douk."

C is a double vein; it has been traced about 400 yds. and worked to a small extent on the hill top, where it averages about 2 ft. in thickness.

Vein D has been traced on the fell top for 600 to 700 yds. It is worked on the crest by open-cast and shallow stopes approached from shafts. On the hill slopes there are two levels; No. 2, 530 ft. long, runs back under the crest stopes, which are 40 or 50 ft. above it. No. 1 level, 350 ft. long, lies 15 ft. below No. 2, and about a third of the way in it the vein takes a sharp bend. This vein contains the best barytes, half of it consisting of platy and white spar, and the rest of crystalline masses of the translucent variety. The average width is about 2 ft., but the vein is very bunchy and subject to sudden nips.

Vein E is approached by a drift about 90 ft. below D No. 1 level. It is said to have been followed in this drift for about 300 ft. and to have yielded an average of 2 ft. of good barytes. In April 1921 the drift had caved in about 50 yds. from the entrance, the "rushed ground" being clay with lumps of barytes. Some doubt is entertained as to E being a separate vein, for it may be merely a south-westerly prolongation of D.

It will be seen from the foregoing account that there are as yet no difficulties in mining. Drainage is not likely to prove a serious obstacle, and the new ropeway ensures easy transport. The spar is conveyed to a shoot by carts or sleds from the open workings, and by trams from the levels. A small ropeway carries it on to a main loading station where it is conveyed in 2½ cwt. buckets on a ropeway for a distance of 2,700 yds. to a tramming point near the mill at Hayber Lane. Owing to a landowner's objections the ropeway had to be deflected about 500 yds. north of the mill, and an angle station put in.

At the mill the barytes is washed, graded, and cleared of large rock debris on two picking-grates. The D grade of dark impure barytes is sold as crude to chemical manufacturers. The A grade of good white platy and crystalline translucent spar is milled. The smalls from the picking grates are caught in a trough

and jigged; the poor grade is picked out, and the rest, together with crushed A lump is bleached. The A grade after drying passes through a pair of kibbling stones and two pairs of finishing stones, all of French buhr. The product consists of a high grade white powder.

The mill, which is driven by a 75 h.p. suction-gas plant, minimises handling.

The finished barytes has to be carted about 1½ miles to Warcop Station (N.E.R.).

The output of the A grade averages 20 tons, and that of the D grade about two tons, per week.

The veins have not been tested at depth, but there appear to be considerable reserves within easy reach of the crop. The bottom of the limestone lies at least 100 ft. below the present workings, and if the veins continue to that depth the reserves must be enormous. As these are not dislocation veins but mineral deposits occupying joints widened by solution, their continuance in the rocks below the limestone is improbable.

Scordale Mines.

Scordale Barytes, Ltd., Cails Buildings, Newcastle-on-Tyne.

Situated near the head of Hilton Beck, 2½ miles N.E. of Hilton and 5 miles E. of Appleby.

Maps.—One inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Westmorland, 10 S.W., Ms.

Both barytes and witherite are found in the hillsides surrounding the head waters of Hilton Beck, which is known as "Scordale Beck" above the village. They occur in fissure-veins but more habitually, in flats. In April 1921 barytes alone was being worked. It is won from two old lead levels of the Hilton Mine. These lie to the north of Great Augill, and on the south-east side of the valley. Barytes occurs only in flats. These deposits constitute an irregular bed, pinched out at intervals, lying between the top of the Melmerby or Great Scar Limestone and the hazel, a bed of sandstone from 2 to 6 ft. in thickness, which intervenes between that limestone and the overlying Whin Sill. They average 3 ft. in thickness and vary from a few inches up to 8 or 9 ft. They are most productive when occupying hollows in the limestone.

The spar is mostly high grade platy white barytes, though in places it is superficially iron-stained. Translucent crystalline masses also occur, usually in clay or "muck." Although of high grade this variety is rather more difficult to grind. Black barytes* is not uncommon in some of the workings.

* This variety grinds almost white, or very pale grey. The colour-bands show a pronounced zonal arrangement, and microscopic examination shows that the dusky appearance is due partly to innumerable tiny bubbles, giving total reflection, and partly to minute spicular growths of pyrites, in contrast with the black of the barytes of Shropshire which is believed to be due to bitumen.

Fluorspar, though not found in commercial quantities, is fairly common and generally occurs in loughs towards the top of the flats. Galena, in coarsely crystalline strings, is frequently found at the junction with the enclosing strata; it is sometimes enclosed in barytes. Calcite is not common, and quartz, though reported from other workings in this valley, is absent. Rock-fragments in the flats include limestone and hazel, but whin, although reported from the Amber Hill workings, has not been found at this locality.

The Amber Hill workings, though said to still contain a fair quantity of barytes, are closed. The mineral occurs in similar deposits to those described above, and also in veins. In thickness both the flats and veins range from 1 to 4 ft. with an average of about 2 ft. The deposit has yielded some very high-grade barytes. Flats are known to occur also on the south and east faces of Mell Fell, but are not worked for barytes. In the upper part of the Great Scar Limestone, and below the Whin Sill, witherite was once got from a level near the old crushing-mill. Barytes is said to have occurred near here in a vein and in flats from 3 to 4 ft. thick. The workings, low down in the limestone have been long disused.

The barytes workings lie to the north of Great Augill, and are entered by two of the old lead levels of the Hilton or Scordale Lead Mine. The level by that gill is known as the " Dowska " or Dow Scar Level, and the other, commencing about 200 yds. to the north, as the South Level. The system of working is a kind of pillar-and-stall, the pillars as a rule being dead, or pinched, ground, and little or no timber is required.

The spar is roughly picked and washed on a grate, and then carted $2\frac{1}{2}$ miles to the grinding-mill at Hilton. There it is again washed and picked over a $\frac{5}{8}$-in. grate into A and D grades. Fragments passing through the grate are jigged, while the over-sizes, after further picking, along with A grade lump, which is broken in a rotary crusher to approximately $\frac{3}{4}$-in. cubes, are sent to the bleacher. The smalls go to a second jig giving D grade barytes, and chats, consisting mainly of fluorspar and stone.

The bleachers consist of two lead-lined vats, each of $4\frac{1}{2}$ tons capacity, filled with spar and dilute vitriol, and heated by perforated steam coils. Some hydrochloric acid is added if the barytes is badly stained. When bleached the spar is washed; dried on a kiln; elevated to the milling plant, consisting of a ballmill with steel balls on slotted plates; and ultimately delivered through a screen of 60 mesh per lineal inch, to two pairs of French buhr stones.

Power for the plant is supplied by a 40 h.p. water-turbine, assisted when necessary by a gas engine.

Most of the output consists of the exceedingly fine white flour of A grade. D grade is a yellowish or greyish-white powder. Formerly B and C or intermediate grades were also produced.

The finished material is carted to Appleby (M.R. and N.E.R.) a distance of 6 miles.

The average output is about 20 tons a week; with the large reserves in this mine, and in the immediate vicinity, this amount could be much increased.

Records are known of galena workings in Scordale dating from the 14th century, but the barytes production is a comparatively new feature. The first official record was in 1896, when 70 tons of the carbonate were produced by the Scordale Mining Company. This company continued to produce barytes on a small scale, the maximum being 665 tons in 1902, until 1906, when the Brough Barytes Company took over the workings, and raised the output to 1,230 tons in 1908. Since 1912 the mines have been worked by Scordale Barytes, Ltd.

Dufton Fell Mines.

The mines lie to the south of High Scald Fell, and about 3 miles N.E. of Dufton and 6 miles N.N.E. of Appleby.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Westmorland, 5 S.E., Ms.; 6 S.W., P.

The mines were worked for galena by the London Lead Company about a century ago. They were restarted about 1880, when barytes was also mined. The average annual output was about 500 tons of barytes, the highest being 1,293 tons in 1886. The mines have been closed since 1897. A prospecting-level is now being driven, and if successful the mines will be reopened for lead and barytes.

All the veins were worked for barytes, except the Clovendock Vein. Dobson's Vein is a fault with a downthrow to the south of 27 ft. near Tarn Side, but decreasing to 9 ft. to the west of Great Rundale Tarn. In this vein, near Great Rundale Tarn, perfect casts of barium sulphate in carbonate of lime have been met with.* The Hard Ark, Barrow's and Barrow's Sun Veins are faults with small throws to the north. Gascoign's and White Rake Veins have not been so extensively worked as the others.

The Dufton veins range approximately east and west, and extend vertically downwards in an irregular manner from the strata just above the Five-Yard Limestone, at the top of the fell, through the intervening limestones and Whin Sill to the Melmerby Scar Limestone. The richest deposits occurred near the surface, and also in the Tynebottom Limestone. The workings extend down to the Melmerby Scar Limestone, but at this horizon yield no lead-ore and very little spar. With increasing depth the veins narrowed and the barytes became more "brangled," that is, mixed with country-rock, iron-stained, &c.

Mr. Vincent Bramall† states that barytes, in addition to occurring in veins, was also found in "flats," and that the latter

* J. G. Goodchild, *Proc. Geol. Assoc.*, Vol. viii, 1883, p. 196.

† "The Mining, Manufacture, and Uses of Barytes in the Neighbourhood of Appleby, Westmorland," *Trans. Inst. Min. Eng.*, Vol. lxi, 1921, Part I., pp. 42–46.

deposits were generally of the crystalline glassy variety. A crystal of barytes, from Dufton Fell, weighing about one cwt. and believed to be the largest ever recovered, is now deposited in the Museum of Practical Geology, Jermyn Street, London. Recently Mr. Bramall found a crystal, about two-thirds of a cwt., which he presented to the Manchester University Museum.

Silverband Mine.

(*Idle.*)

Situated about a mile north-west of Knock Fell and 7 miles north by east of Appleby.

Maps.—One-inch New Series Ordnance, 25; Old Series Geological, 102 N.E.; six-inch Westmorland, 5 N.E., Ms.

This mine* was worked for galena from the beginning of last century by the London Lead Company, but it has been abandoned for many years.

There are several veins running nearly east and west through the Yoredale Series from the Great Limestone downwards. The chief one is the Silverband Vein. This vein has been worked for lead-ore to a depth of several hundred feet. It is said to vary from 10 to 60 ft. in thickness and to carry a considerable amount of barytes. Several thousand tons of barytes lie in the extensive dumps, but unfortunately the bulk of the mineral from this mine is badly stained and only suitable for crude barytes. Witherite and some pyrolusite and limonite are also reported.

Middle Fell Mine.

(*Idle.*)

J. G. Reynoldson, Esq., Brough, near Appleby.

Situated near Middle Fell, Barras-on-Stainmore, and about four miles S.E. of Brough.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Westmorland, 24 N.W., Ms.

This was the first mine to raise barytes in Westmorland. It was opened in 1885 and continued working for about ten years. The largest output was in 1886 when 500 tons of spar were recorded, but not more than 1,500 tons in all were obtained. The mine was closed owing to the irregular occurrence of the flats. The barytes occurs in a series of flats, and also in a vein filling a vertical fault, with a small down-throw, which traverses the Yoredale rocks. The vein, coursing N.N.W. to S.S.E., has been traced from Mousegill Viaduct, near Barras Station, to the eastern slope of Middle Fell. It carries pure good class

* Information from "The Mining, Manufacture, and Uses of Barytes in the Neighbourhood of Appleby, Westmorland," by Vincent Bramall, *Trans. Inst. Min. Eng.*, Vol. lxi, 1921, Part I, p. 42.

white barytes and a little galena. The barytes often occurs in translucent crystalline masses.

Workings both in the vein and the flats are confined to the Great Limestone in the proximity of Middle Fell, and there are indications that the vein carries white barytes still farther south.

Bleawick.

(*Idle.*)

This mine lies on the east side of Ullswater* and a little to the east of Bleawick, locally Blowick.

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Westmorland, 12 N.E., P.

Pink barytes occurs in a main vein with subsidiary strings, in rocks of the Borrowdale Series, which are generally full of quartz strings. The main vein runs east and west, and is practically vertical wherever exposed. It thickens and thins rather rapidly and usually has less than 1 ft. of barytes and frequently only 2 or 3 in. The mineral is of pink colour, slightly darker than that of Ruthwaite, but otherwise similar.

A short level, reported to be in search of copper-ore, was driven along the vein into the hill. A small dump of barytes and deads still lies near the mouth.

Greenside Mine.†

Greenside Mining Company, Glenridding, Penrith.

Situated near Glenridding on the eastern slopes of Helvellyn, about 1½ miles west of the head of Ullswater.

Maps.—One-inch New Series Ordnance, 29; Old Series Geological, 101 S.E.; six-inch Westmorland, 12 N.W., P.

It is stated elsewhere‡ that the veinstuff of the Greenside Lode is chiefly quartz, but in some "places barytes is pretty abundant." This appears to have been the case in some of the old workings now abandoned and inaccessible. The present workings contain little or no barytes.

Knipe Tarn.

(*Idle.*)

Situated 2½ miles south-east of Bowness.

Maps.—One-inch New Series Ordnance, 39; Old Series Geological, 98 N.E.; six-inch Westmorland, 37 N.E., Ms.

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* Mentioned in "The Geology of the Northern Part of the English Lake District" (*Mem. Geol. Surv.*), 1876, p. 59.

† For a detailed description of this mine *see* Special Reports on the Mineral Resources of Great Britain, Vol. xxii, "The Lead and Zinc Ores of the Lake District" (*Mem. Geol. Surv.*), 1921, pp. 14–19.

‡ In "The Geology of the Northern Part of the English Lake District" (*Mem. Geol. Surv.*), 1876, p. 54.

"A vein of pink sulphate of baryta with a little galena has been opened out by the roadside a quarter of a mile south-west of Knipe Tarn."* Later on the works are said to have been abandoned as unprofitable.

The vein runs approximately east and west through Bannisdale Slates. It varies in thickness up to 8 ft., but the greater part is country-rock with strings of galena and barytes and a little quartz.

A portion of the vein has been worked out from the crop, where thin strings of barytes of poor quality are seen still adhering to the walls.

A level has been driven into the hillside from the open work, and a shaft sunk to a depth of 60 ft.

The dumps of this mine have been used for road metal for more than 20 years. They contain a small amount of barytes.

Other Occurrences of Barytes in the Neighbourhood of Brough.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.

On Stainmore Common and along the main road from Middleton to Brough there are several old "hushes" and workings along six or more lead-bearing veins. These veins, which traverse the Carboniferous Limestone Series from the north-east to south-west, are believed locally to be a continuation of those of Lunehead Mine (p. 52); the vein seen near Shot Moss and to the north of Seavy Rigg Farm is identified with the Old Sun Vein of that mine.

Barytes from the numerous dumps and shallow open-workings has been collected and carted to Brough for grinding. Much of it is of high quality and needs no washing or bleaching. The six veins yielding this mineral lie between Hillbeck High Fell on the north and Swindale Head House on the south. Some of them have been traced as far as Hillbeck Hall within a mile of Brough.

5.—Yorkshire.

General Account.

Barytes has been worked in Yorkshire on a small scale for upwards of 40 years. The Lunehead and the Greenhough (Plate IV) are the only active mines.

The veins are all in the north-western part of the county, the best of them being in the Carboniferous rocks of the Pennine Chain. They probably belong to the same extensive mineral province as those in Westmorland and Durham. At Lunehead the veins, formerly worked for galena, are numerous. The

* "The Geology of the Country around Kendal, Sedbergh, Bowness, and Tebay" (*Mem Geol. Surv.*), 1888, p. 18.

workings, still shallow, are easily drained, and the spar is of good quality, so that the mines can be wrought successfully in spite of the 9 miles of road transit required to reach the railway. At Greenhough, the barytes is mainly obtained from flats in the Carboniferous Limestone.

The only part of Yorkshire holding good reserves is the old lead-mining centre situated in Upper Swaledale, which has poor railway facilities.

Details of Mines.

Lunehead Mines.

J. G. Reynoldson, Esq., Brough, near Appleby, Westmorland.

The mines lie six miles N.E. of Brough and about eight miles S.W. of Middleton, on the main road between the two places.

Maps.—One-inch New Series Ordnance, 31; Old Series Geological, 102 S.E.; six-inch Yorkshire, 3 S.E., P.

This mining field is of considerable antiquity as evidenced by the numerous shallow workings and old "hushes."* It was wrought extensively for galena in the earlier part of last century, but barytes, being then unsaleable, was either left in the mine or thrown on the dumps. The commercial production of barytes at Lunehead commenced about 35 years ago, since when the output has been fairly large and continuous.

The Lunehead veins are in faults of small throw and high inclination, ranging from north-east to south-west through the Yoredale Beds about the horizon of the Great Limestone. They occur in a belt, nearly half a mile wide and over two miles long, in the following order from north to south: Wensley, Band or Reid's, Old Swan or Nacky, White or Glassy, Little White, North and South Cavern, and No. 1 Veins. In addition there are several strings. All carry more or less barytes, and some contain pockets of witherite.

The Wensley Vein has yielded galena rather than barytes, so that a description of it is here unnecessary.

Reid's Vein, with a small throw to the south, has been worked in what is known as the Back Level. In breadth it proved variable, but probably averaged three feet. In one place, after giving off strings to the north, it is completely nipped, but picks up again farther west. The north cheek is covered with "douk" which at times causes trouble. It contains some good barytes which occurs in pockets.

The Old Sun, or Nacky Vein, formerly worked for lead-ore on the west side of the horse-level, carries a good deal of barytes. The main barytes workings are to the east of the horse-

* "Hushing" was an ancient method of locating and working veins by deflecting watercourses in the vicinity of lodes, the gully thus formed being known as a "hush." *Cf.* the Welsh "Hwch" used as a prefix at the old Minera Mines, and referring to a gully cut below a reservoir for washing ore.

level. Where the roof of the workings has collapsed, limestone is seen on the north, faulted against shale, the throw being about 30 ft. to the south. The average width of the vein is between 7 and 8 ft.; at times it increases to 16 ft., but never narrows much below 4 ft. It consists entirely of barytes. The reserves are large, and apart from some ironstaining, of good grade.

The spaces left whence the " old men " robbed galena from the sides, provide access to surface water, which causes rushed ground requiring heavy timber. This appears to be the only difficulty in working the vein.

The White, or Glassy, Vein contains high-grade transparent or translucent barytes mixed with " muck." It varies in thickness from a few inches to 5 or 6 ft. It is frequently pockety and makes bad, heavy ground. It has been worked to a small extent on the east side of the mine.

The Little White Vein, though containing some barytes, is regarded as poor and has received but little attention.

The Cavern Veins are close together, and are associated with some large caverns in the Great Limestone, from which their name is derived. These occur chiefly on the east and were once filled with red clay, at the bottom of which some lead-ore was found. The walls contain small pockets and strings of barytes and galena. The North Cavern Vein, though irregular and pockety, averages about two feet in width, mostly of good grade barytes, with some galena on the walls. It has been worked for barytes on the west side of the mine where it contains patches of witherite. The South Cavern Vein is of less importance, and is considered to be of an inferior quality.

No. 1 Vein contains much high grade barytes though it deteriorates eastward. To the west, where it has been worked, it averages about a yard in breadth. The chief difficulty of winning this deposit is the long haulage of the material underground.

There are numerous shafts on this property, but the main haulage-way is the adit-level. This is a cross-cut trending southward from the mine shafts; it serves as a main tramroad and drain. Except for a few small sumps the workings are all above its level.

The barytes is hand-picked and grouped into (1) grinding grades of fairly pure spar, (2) impure spar, which is sent away to chemical and lithopone manufacturers as crude small lump. The grinding grades are washed over a grating. The purest spar is selected for A grade; the rest, with smalls from the grate which are jigged, forms grades 2 and 3. Grade A, after crushing, is bleached in lead-lined vats containing sulphuric acid heated by perforated steam-coils. After washing and drying it is milled to a fine white powder by being passed through a pair of kibbling stones and two pairs of finishing stones, which are all horizontal and consist of French buhr. Grades 2 and 3 are similarly ground but produce grey or yellow powders.

The barytes is carted to Warcop Station (N.E.R.), a distance of 9 miles.

From the commencement of barytes mining at Lunehead, about 35 years ago until 1898, the annual output ranged from 400 to 500 tons. From 31st December 1914 to 31st December 1920 the output is given below in tons.

	Ground.	Crude.
1915	929	681
1916	1,172	832
1917	984	1,210
1918	1,223	588
1919	1,094	494
1920	1,171	363

The average production of lead-ore during the same period amounted to 12 tons per annum.

There are large reserves; the Nacky Vein, the greatest producer, is showing well on the east between the surface and adit level; some of the smaller veins are almost untouched and none shows signs of deterioration in depth.

Skeleron Mines.

(*Idle.*)

Situated 1 mile south-east of Rimington, near Clitheroe.*

Maps.—One-inch New Series Ordnance, 68; Old Series Geological, 92 S.W.; six-inch Yorkshire, 183 N.W., Ms.

As shown by the old workings, there are at least six distinct veins which range between N. 10° W. and W. 35° N., with the exception of one which ranges N. 10° E., roughly parallel to a great fault running through Rimington. The country-rock is Carboniferous Limestone with associated chert-beds, but near the veins the rock becomes dolomitic, and is known as "Dun Limestone." The veins contain argentiferous galena, barytes, calamine, calcite, and a little fluorspar and dolomite. The vein most recently worked varies in width from 6 in. to 6 ft., but little is known regarding the thickness of the others. Much of the barytes appears to be a good white platy variety with iron-staining along the joints; it was sold as second quality material. The lead-ore contains a fair amount of silver.

The oldest workings were conducted entirely from shafts sunk from the surface, but later workings were carried on from a level which was driven from the beck near the old smelting-house. In the old days the mine was worked for lead and silver and the rest of the material thrown on the dumps, but about 1880 barytes was also dealt with, of which a fair amount still remains in the dump. Since then some attempt has been made to work calamine.

The barytes was washed, cobbed, and scrubbed to get rid of some of the coating of iron-oxide, and was apparently then sold to the manufacturers for further treatment.

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* The "Geology of the Burnley Coalfield" (*Mem. Geol. Survey*), 1875, p. 173.

All material was taken by cart to Rimington Station on the Midland Railway, a distance of about 2 miles.

The mines were much worked in the reign of Queen Elizabeth by William Pudsay, Lord of Bolton-in-Bowland. An attempt was made to reopen them about 1830 when the level was driven, but apparently without much success. Still later, about 1867–8, a shaft was sunk in a field east of Stopper Lane, with the expectation of reaching the lode, but it was begun too far to the east and ran entirely through micaceous clayey shale. About 1880 the mine was worked for barytes, and since that time has been worked for brief periods at long intervals, chiefly for barytes and calamine.

Grassington Mines.

(*Idle.*)

Situated on Grassington and Hebden Moors, north-east of Grassington.

Maps.—One-inch New Series Ordnance, 61; Old Series Geological, 92 N.E.; six-inch Yorkshire, 134 N.W., N.E., Ms.

There are numerous veins in this area varying in direction from north-west to west. They have generally been formed along faults, which affect the lower portions of the Millstone Grit, and the Carboniferous Limestone. They were extensively mined for lead about 40 or 50 years ago. Some of the shafts are fairly deep but are now flooded; surface-workings and shallow pits have been sunk on the veins at intervals of a few yards.

In the Bycliffe Vein, formerly worked at the Bycliffe Mine, which is the most northerly of this series, barytes appears to have been the dominant vein-mineral. Apparently there are large open cavities in the veins, for a small amount of stalagmitic and stalactitic calcite is present on the dumps, but fluorspar is practically absent. In the " dead " dumps barytes is seen in grit, in strings rather thicker than elsewhere on the moor, and it forms the bulk of the finer dumps (probably jig-tailings). It is fairly white though slightly iron-stained and not hard. It contains little galena, but is occasionally stained green, probably from the presence of copper-ore.

In the southern veins of the Moor proper, fluorspar and barytes occur in places only, and then in thin strings. The fluorspar is pale yellow to colourless and forms the greater part of a small jig-dump of the Moss Mine, though in the southern veins of this mine there is more barytes than fluorspar.

At Yarnbury, about a mile north-east of Grassington, in the south-west vein, barytes is local and there is little fluorspar, but on the north-east vein both minerals are more common in the form of thin strings, but not in workable quantities. The fluorspar is amber yellow in colour, and of good quality, while the barytes is dirty white but otherwise similar to that of the other veins. Some dumps of finer material from the jigs carry fair quantities of both minerals but are not extensive.

Cam Pastures.

*(Abandoned lead mines.)**

Situated about a mile north of Kettlewell.

Maps.—One-inch New Series Ordnance, 50; Old Series Geological, 97 S.W.; six-inch Yorkshire, 98 S.E., P.

There are several veins here in the strata immediately above and below the top of the Great Scar Limestone. They range N.N.W. and N.W. by S.S.E. and S.E., but there are also several almost east and west lodes. Many are simple fissures running through dolomitic or "dun" limestone, and, together with blocks of this rock, contain galena, calcite, fluorspar and barytes. On the east, fluorspar appears to have been the commonest spar, along with a little barytes. Towards the middle of the course, calcite in peculiar spherical masses, with concentric and radiating structure, becomes rather abundant, and there is less fluorspar, while there is a little barytes also, as on the east. On the west fluorspar is not abundant, calcite not common, and barytes occurs only in thin strings in the "dun" limestone, which as elsewhere forms the bulk of the vein-filling.

None of the barytes is of good quality; it is dirty white in colour and mixed with limestone.

The fluorspar is mostly pale yellow or almost colourless, with occasionally a little of the purple variety. Some of the tailings, probably from jigs, contain a fair proportion of fluorspar, but the dumps are small.

There are numerous shallow shafts, sunk at short intervals, directly on the veins, but except on the west, near Starbottom, operations appear to have been on a small scale. The big vein, near Starbottom, has been worked partly from the crop and partly from shafts and an adit driven into the hillside about a third of a mile south of the village.

Little is known of the history of these mines; they have not been worked for many years.

Middlesmoor and Hawkswick Moor.

(Abandoned lead mines.)

Situated between Kettlewell and Arncliffe.

Maps.—One-inch New Series Ordnance, 50; Old Series Geological, 97 S.W.; six-inch Yorkshire, 115 N.E., P.

The veins of this area keep to the same horizon as those of Cam Pastures, *i.e.*, the Hardraw Scar and the top part of the Great Scar Limestones, and run through similar courses of "dun" limestone. At the north end of Middlesmoor there are three east-and-west veins, but on Hawkswick Moor and the south side of Middlesmoor there are numerous veins running east and west, north and south, and north-west to south-east.

* "The Geology of the Country around Ingleborough" (*Mem. Geol. Surv.*), 1890, pp. 85, 86.

Just south of Moor End the ground has been extensively turned over on the three east-and-west veins, but in all cases the bulk of the vein-filling, to judge from the dump, is rock. Such fluorspar as is present is the pale yellow or colourless variety similar to that of Cam Pastures. Barytes is rather more abundant than at Cam Pastures, and one string is in places about 8 in. thick. A good deal of it is white and of fair quality, but it does not appear to be in sufficient quantity to be worth working. The jig-tailings consist largely of limestone- and sandstone-crushings.

On the network of veins on the west of the moor there are numerous old workings, and some of the dumps contain more barytes than do those on the east.

Some of these mines were in operation between 30 and 40 years ago.

Raygill Mine.

P. W. Spencer, Esq., Lothersdale, Cononley.

Situated $4\frac{3}{4}$ miles N.E. of Colne.

Maps.—One-inch New Series Ordnance, 68; Old Series Geological, 92 S.W.; six-inch Yorkshire, 184 N.E., P.

There are three veins and numerous strings of barytes in the Carboniferous Limestone in the Raygill Delf. The veins have not been mined for some years, but barytes from the strings is obtained incidentally in quarrying the limestone. The two principal veins, about 100 yds. apart, run almost east and west, parallel to a fault with a considerable throw to the south, which runs past Raygill Clough from Surgill Rough to between Green Hill and Dowshaw Delf. These two veins hade to the south, and have a thickness varying from a few inches in the "pinches," up to 6 ft. in the "swells," with probably an average thickness of 2 ft. The third vein, which is thinner, is a cross-course between the two parallel veins and ranges roughly north-east by south-west. In the vicinity of the veins the limestone is unsuitable for quarrying purposes.

The barytes is mostly white, with ironstaining along the cracks. Some of it is platy, and some is a fine-grained chalky-looking variety known as "caulk." Calcite is abundant, and some fluor was noticed in strings. One thin string contains dialogite, the carbonate of manganese.

The northern vein, with a horizontal extent of about a quarter of a mile, was at one time followed underground to a depth of 200 ft. The other veins have been worked chiefly in conjunction with quarrying for limestone.

The barytes mine, about 1880, produced 2,000 tons per annum. The workings are now flooded, and large quantities of overburden from the quarry have been tipped into them.

The barytes obtained from the strings in the quarry does not amount to above 1 or 2 tons per annum at the outside, and

practically none has been sold for some time. The mineral is not treated in any way before sale.

Cononley Lead Mine.

(*Idle.*)

Situated at Weasel Green, 3 miles south-west of Skipton.

Maps.—One-inch New Series Ordnance, 69; Old Series Geological, 92 S.E.; six-inch Yorkshire, 184 N.E., P.; 185 N.W., P.

At Cononley a fault, with a general north-westerly and south-easterly trend in the lower beds of the Millstone Grit, is, for part of its course, a mineral vein. It extends from Cononley Moor through Lower Weasel Green and across Glusburn Moor, but the only working of importance was that of Weasel Green, known as the "Cononley Lead Mine." This mine ceased operations as a lead mine about fifty years ago, but the dump was worked for a short time for barytes between 30 and 40 years ago.

The dumps are fairly extensive and contain a good deal of barytes, which appears to have been the chief and almost the only vein-stone, although some witherite and calcite are said to have been found. The barytes is mostly the iron-stained, white, tender and platy variety, sometimes slightly pink.

Virgin Mine.

(*Idle.*)

Maps.—One-inch New Series Ordnance, 41; Old Series Geological, 97 N.E.; six-inch Yorkshire, 52 S.W., Ms.

Although ore-mining was carried on for many years in Wensleydale, the Virgin Mine seems to have been the only commercial barium producer; in the Home Office "Report on Mines," &c., for 1887, "Virgin Moss"* was stated to have produced 8 tons of barium carbonate in the year; the mine was also listed in 1889 and 1890, but no returns were given.

The vein, which is known as the "Virgin String," runs for $1\frac{1}{2}$ miles in a N.W. direction across the fell-top. The mine-mouth, directly on the vein, is still open; it is situated 3 miles W. 30° N. from Redmire.

Throughout the course of the vein (which was a producer of galena) there are numbers of old shafts, and on the waste-heaps barytes occurs in quantities; but it is of a pronounced brown colour, and is crystallised in layers only $\frac{1}{4}$ to 3 in. thick.

At the mouth of Virgin Level, fragments of witherite are to be seen on the waste-heaps, intergrown with fibrous barytes and calcite, the latter in large well-grown crystals. In a corner of the old loading sheds there lie one or two tons of dressed carbonate; it has, as usual, a translucent yellowish-green colour and radiate internal structure, and appears to be of fine quality.

* Locally, and also on the Ordnance Survey maps, the name is given as "Virgin Mine."

The witherite is said to have been found, not in the vein proper, but in a "flat" in the limestone, about 200 yds. in from the mine-mouth. This "flat" was 15 ft. wide and 2 to 3 ft. high, the carbonate lying in a solid body. Little was left when the workings were abandoned, and none of any account was ever got in the vein itself.

Catholes Clough.

(Idle.)

Situated in Catholes Clough, opposite Robin Mill on Burnley Road, 1½ miles from Todmorden.

Maps.—One-inch New Series Ordnance, 76; Old Series Geological, 88 N.W.; six-inch Yorkshire, 229 N.W., Ms.

This vein is connected with a N.W. and S.E. fault which brings the Third Grit on the south-west against the Kinder Grit on the north-east. It is said to have been from 3 to 18 in. thick, and to contain galena and copper-pyrites, with barytes as the chief gangue-mineral in addition to a little calcite.

Half a mile up the clough, a drift, three-quarters of a mile in length, was driven for the vein, which was worked originally for lead, and also for a short time at a later date for barytes.* A small heap of barytes lies at the bottom of the clough near the supposed position of the level. The spot is known locally as "the old lead mine."

SWALEDALE.

Along the northern slopes of Swaledale certain members of the intricate network of galena-bearing veins on Melbecks and Reeth Moors have a gangue of barytes, sometimes accompanied by witherite, but there has been practically no commercial production of these spars. The mines are 14 to 20 miles from the nearest railway, at Richmond.

There are, along the same vein-complex, three mining centres, all of which were formerly active producers of lead-ore. They are reached from Muker, Gunnerside and Reeth respectively.

Muker District.

The old Swinnergill Lead Mines are 2 miles N. of Muker; here were worked a set of parallel and coalescing E. and W. veins, which have been followed westwards past Keld, a distance of 2 miles through Yoredale rocks: eastwards they traverse Millstone Grit strata, in which they were non-productive. These veins are thought to be the westerly branches of the Old Rake Vein, so extensively worked at Old Gang and Surrender.

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* James Kerr, "Lead Mining in the Districts of Stansfield, Holmes Chapel, Rossendale, and Great Hambledon in N.W. Yorks and N.E. Lancs," *Trans Manch. Geol. Soc.*, Vol. xiii, 1876, p. 355.

At Swinnergill the North, Middle and South Branches were mined, being connected by levels. The gangue was mainly calcite, with some barytes; galena, mostly came from the centre of the vein; fluorspar, cerussite and zinc-blende also occurred in small quantity. In pockets in the limestone walls there are occasional bodies of witherite, but whether this is in payable quantities is not known.

Gunnerside District.

The Friarfold Vein seems to be the most promising for barytes in Swaledale. This is especially the case between Surrender mine-shafts and the valley of Gunnerside Beck, a distance of 2 miles. The vein intersects the highest beds of the Carboniferous Limestone Series in an E.N.E. direction, and for the entire distance has been extensively mined for lead-ore. Judging from the nature of the great spoil-heaps the gangue, as is stated locally, must have consisted wholly of barytes.

The vein was slit only along the centre for galena, and as little barytes as possible brought to the surface; it seems likely therefore that large quantities of barytes are stored in the old workings.

The barytes from the Friarfold Vein is in part white, translucent and pure. The commonest samples are opaque white masses with a slight bluish or pinkish tinge; in others the pinkish tinge is strongly marked. Some have a black and opaque appearance which is presumably due to carbonaceous matter.

Reeth District.

This is the only part of Swaledale where barium spars have been produced commercially, and the amount seems to have been extremely small. In the Home Office "Report on Mines, &c.," for 1892, Old Gang Mine is stated to have produced 12 tons of carbonate of barium. According to Mr. Cherry, the estate agent, this carbonate came from a pocket in the Lucky Vein, a branch of the Old Rake; and he states that the mineral was plentiful, but rather "dirty," occurring as irregular bodies up to 4 ft. wide, and holding a little blende and galena in the centre.

On the waste-heaps behind the smelt mills specimens of pale yellowish-green witherite can still be picked up in abundance; it usually grows on, or is interleaved with, thin bands of more or less granular barytes, which can readily be detached.

On the other side of the stream, opposite the smelt mills, the old waste-heaps show layers rich in barytes, generally of a rather low grade, pinkish, and streaked with grey matter. Mr. Cherry believes this comes from either the Old Rake, North Rake, or Friarfold Veins, all of which contain barytes in bodies occasionally as much as 6 ft. across.

Half a mile west of the Old Gang smelt mills, on the waste-heaps at the mouth of Victoria Level, there are quantities of a translucent white or very pale yellowish-green mineral, with

mammillated surfaces and a finely-radiate internal structure. On further examination this "water-spar" (as it is known locally), proved to be a mixture of witherite and strontianite. The exact source of this peculiar mineral is not certain, because the Victoria Level cut two veins, the "Watersikes" and the "Watersikes Sun"; but the latter was the more distant from the level mouth, and probably the last to be worked, so that debris from it would figure largely on the surface of the waste-heaps.

In all the old mining operations round the Old Gang and Surrender Mines, barytes, apart from the few tons raised in 1892, was neglected and was only taken out where necessary to get at the galena and blende. An examination of the estate-books shows that all material coming out of the mines was classified under two headings, "ore" and "rider," the latter including calcite, country-rock, barytes or gangue generally. In all probability, therefore, good reserves of barium spars, especially sulphate, remain, and would not be difficult to get at, the veins having already been opened out extensively, and the strings of ore removed. The mines are 16 miles by road from the nearest railway, at Richmond.

In Upper Swaledale, barytes was also noticed on the waste-heaps of the Smarber Mine, by the roadside 1½ miles east by south from Gunnerside Bridge. This mine produced galena from the Fryer's Intake Vein; it has been quoted* as a locality for fluorspar, but not in commercial quality.

NIDDERDALE.

Greenhaugh Mine.

Greenhaugh Mining Company, Ltd., Princes Street, Harrogate

Greenhaugh, or Greenhow, mines are situated on Greenhaugh Hill, 600 yds. south-west of Keld Houses; and on the watershed between the Nidd and the Wharfe valleys, 4 miles west of Pateley Bridge.

Maps.—One-inch New Series Ordnance, 61; Old Series Geological, 92 N.E.; six-inch Yorkshire, 135 N.W., S.W., Ms.

The mines have been worked for lead-ore since Roman times. In the 19th century they were worked continuously up to 1890, when they were closed owing to the low price of lead and to the antiquated mining methods employed. They were reopened in 1916, and barytes was first sent away in 1918.

Massive Carboniferous Limestone forms the core of an east-and-west anticline, overlain to the north and south by the grits and shales of the Millstone Grit. The Carboniferous Limestone is bounded on the south by one of the east-and-west Craven Faults, which in places becomes a rich galena-bearing lode. The

* "The Geology of the Country around Mallerstang, &c." (*Mem. Geol. Surv.*), 1891, pp. 165, 168.

whole of the limestone mass is highly mineralised. The principal veins lie along east-and-west fissures and are locally known as " Rake " veins. Many north-and-south veins, locally called " cross " or " gulph " veins, intersect these, and both are most productive at their points of intersection. The veins usually prove unproductive when followed from the limestone to the grits and shales. Rich flats also occur at several horizons in the limestone, in association with the veins.

The barytes has so far come from flats in Nursery Knot Plantation to the north of Dry Gill. Fluorspar and calcite also occur. The dip of the limestone and the flats is about 12° N. The workings extend in an east-and-west direction for about half a mile, and northwards for about 300 yds.

The veins have recently only been worked to a depth of 35 fms. from the surface. The old workings extend to depths of 72 fms. and show no sign of impoverishment. The levels have been drained by a day-level, no pumping having been required. Two disused shafts have been equipped with steam winding-engines to fully explore the old workings, in which the former miners stored away the barytes.

The barytes is white and crystalline, though occasionally iron-stained. The crude material was hand-picked and washed, three grades being produced according to relative purity. From the mine, alongside the Skipton-Pateley Bridge main road, the material was conveyed by motor-wagons to Pateley Bridge station (N.E.R.) in Nidderdale over an excellent but hilly road.

In 1918, 400 tons were mined; in 1919, 530 tons; while in 1920 the output was 150 tons, the falling off being due to the lack of demand.

Barytes is a predominant constituent of many of the dumps of the old mines in the neighbourhood of Greenhaugh. Large quantities of it are found in the dumps of the Cock Hill, Merryfield, Providence, Prosperous, and Sunnyside lead mines in the Merryfield valley, which lies 1 to 2 miles north of Greenhow Hill, and 4 miles west of Pateley Bridge. These mainly occur on an east-and-west vein extending over a total distance of 8 miles from Grassington Moor to within a mile of Pateley Bridge. The country-rock consists of grits, sandstones, and shales, of the Millstone Grit formation.

The Permian Limestone on Forest Moor, near Knaresborough, has been noticed by Mr. G. V. Wilson to contain cavities filled with barytes, with occasional crystals of celestine. The largest lumps of barytes seen were about 1 foot in diameter.

At the Lolly Mine, on the south bank of the Nidd, between Ramsgill and Lofthouse, witherite in radiating masses has been noted by Mr. Wilson. The vein was worked for lead, but the witherite was collected and exported to Germany.

6.—Lancashire.

Details of Mines.

Anglezark Moor.

(*Abandoned lead mine.*)*

Situated on the east side of the Liverpool Waterworks, near Chorley.

Maps.—One-inch New Series Ordnance, 75; Old Series Geological, 89 N.E.; six-inch Lancashire, 78 S.W., P.

There are two lodes: one, on the north, along Black Brook, is exposed in an old sandstone quarry near White Coppice, and the other runs north-east and south-west along the river Yarrow. Both are fault-veins in the Millstone Grit. Near the surface the northern vein carries lead-ore only, mainly in the form of anglesite. The southern vein has been exploited, but the workings are not extensive. In the numerous small dumps, galena, cerussite, and anglesite were noticed along with a little blende and copper-ore. Barytes and witherite occur, but there is probably less than a ton of barium minerals in the whole of the dump. The barytes is of fair quality, with slight iron-staining, and not hard; it carries occasional streaks of lead. The witherite is exceedingly good white, though it occasionally contains specks of blende. The mines have long been abandoned.

Goodshaw Hill and Cribden.

Maps.—One-inch New Series Ordnance, 75; Old Series Geological, 89 N.E.

The occurrence of galena with some barytes at these localities has been recorded by Mr. James Kerr.†

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* Described in "The Geology of the Burnley Coalfield" (*Mem. Geol. Surv.*) 1875, p. 173.

† "Lead Mining in the Districts of Stansfield, Holmes Chapel, Rossendale, and Great Hambleden in N.W. Yorkshire and N.E. Lancashire." *Trans. Manch. Geol. Soc.*, Vol. xiii, 1876, p. 351.

History of Mining ... Derbyshire
Leslie B Williams
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CHAPTER III.

THE MINES OF DERBYSHIRE, SHROPSHIRE AND THE WELSH BORDER.

1.—Derbyshire.

General Account.

Prior to 1914, Derbyshire was a small, though regular, producer of barytes. In 1892 the output amounted to 2,705 tons, but for the eight years before 1914 it had declined to less than 300 tons annually. From that year onwards the following are the quantities of barytes given as the output from mines and quarries* :—

	Output in Tons
1914	1,196
1915	529
1916	4,460
1917	4,648
1918	6,856
1919	7,300

These figures, however, give no idea of the actual amount of barytes got from Derbyshire during the years in question, since much more was obtained by re-treating old lead mining dumps than by mining and quarrying. No estimate can be made of the amount of barytes got in this way.

The spar is confined to the Carboniferous Limestone, and occurs in veins, pockets, pipes and flats. In nearly all the principal veins fluorspar is confined to the part of the vein nearest the eastern margin of the limestone-tract and is replaced by barytes inwards towards the central part of that tract, the barytes in turn giving place to calcite. The characters of Derbyshire barytes have already been referred to in the Introduction (*see* p. 2).

The crystalline variety is known locally as "boulder" or "tush." The massive material is called "caulk" or "cawk" —possibly a corruption of "chalk," as it is quite chalky in appearance. For convenience in description the terms "boulder" and "caulk" are used below.

The area (Plate V.) in which barytes is found extends for a distance of 20 miles from Castleton to Wirksworth. Its maximum breadth is about 3 miles, but this is exceptional. Since the grade of the material is low, a detailed list of the occurrences in such an extensive area is out of the question, and only the principal localities receive attention below.

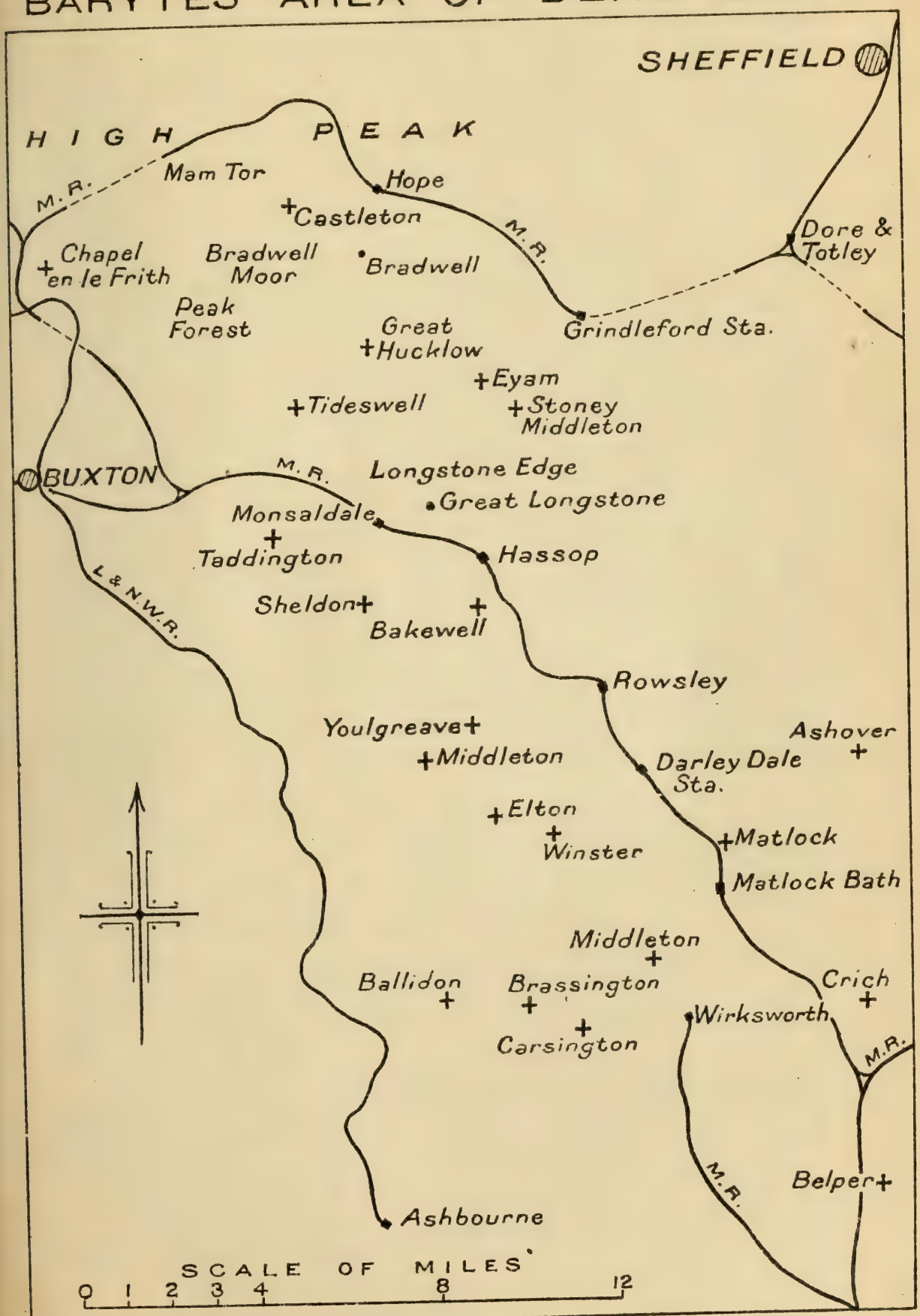
Details of Mine.

Bradwell Moor.

Maps.—One-inch New Series Ordnance, 99; Old Series Geological, 81 N.E.; six-inch Derbyshire, 9 S.E.; 10 S.W., Ord.

* "Mines and Quarries: General Report with Statistics," (*Home Office, Parliamentary Papers*), annually.

BARYTES AREA OF DERBYSHIRE.



Charles & Read, Ltd. *Photolitho.* 548.

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In this area barytes occurs in varying amounts in many of the veins.

The Dirtlow Rake, coursing W. 35° S., has been worked for lead from Pindale to Oxlow End, a distance of 3 miles. Caulk has been got from the old dumps along almost the whole length of the vein, and on the rakes and scrins which branch from it through the Hazard, Portaway and Old Moor Mines.

Near the Holland Twine Mine the Dirtlow Rake, at a depth of from 7 to 8 fms., showed white and red barytes in the middle of the vein, the sides being occupied by calcite. Below this the barytes was less abundant and was absent at 40 fms.

Between the Portaway Mine and Rowter Farm barytes occurs in several places in the form of concretionary and radiating masses, associated with lumps of grey decomposed limestone, in a brown clay overlying limestone. Occurrences of this type have been noted at a point just south of Rowter Farm, on the line of the New Rake vein; again some 200 yds. further south on the line of a small vein running parallel to the New Rake, and also just north of the Portaway Mine on a small vein which is approximately parallel to the New Rake. These occurrences are interesting as illustrating a type of deposit which has yielded large quantities of barytes in the United States, *e.g.*, Missouri, Tennessee and Kentucky. The presence of barytes, in workable quantity in residual clay derived from limestone or dolomite, does not appear to have been noticed elsewhere in Great Britain. Both crystalline and massive forms occur. The shape of the masses frequently suggests that some solution and redeposition of barytes has taken place during the decomposition of the limestone; but even in the veins there is often much botryoidal material of a similar character. All the smaller fragments in the clay seem to be angular.

These masses have been worked occasionally on a small scale during the past few years by means of shallow open pits up to 10 ft. deep. Some pits are almost barren, while others only a few yards away yield large quantities of mineral, as much as 50 tons having been got from one of them.

About a mile south of this locality the Cop Rake courses east and west between the Oxlow Rake and the Moss Rake. It is rich in caulk, and there seems to be little other vein-stuff, but it is not being mined.

At the Hall Mine, about half a mile south of Pindale, caulk and fluor were worked some 6 or 7 years ago. The caulk is of fairly good quality and rather less discoloured than is usual with this variety, but the vein was only about 18 in. wide.

The workings on Bradwell Moor are not well situated for transport, as they are 3 or 4 miles from the railway over poor roads with heavy inclines.

Middleton Moor and Longstone Edge.

Maps.—One-inch New Series Ordnance, 99 and 111; Old Series Geological, 81 N.E., S.E.; six-inch Derbyshire, 16 S.W., S.E.; 23 N.W., N.E., Ord.

On Middleton Moor, south-west of Eyam, there are many old workings, chiefly along the Dirty Rake, which runs about W. 20° S. The mines have long been abandoned, but the old dumps are still worked for barytes.

South of the Cupola Mining and Milling Company's mill in Middleton Dale as many as five veins, all containing barytes, course south-east. They cross the Dirty Rake nearly at right angles. A crosscut driven 120 yds. south-west into the hillside from just above the mill aims at cutting all five.

The estimated distances from the mouth of the crosscut at which the veins should be intercepted are No. 1, 200 yds., caulk; No. 2, 300 yds., caulk; No. 3, 450 yds., boulder with a little caulk, average width 5 yds.; No. 4, 500 yds., boulder and caulk with a little fluorspar; No. 5, 650 yds., caulk and fluorspar. The distance from the surface at which the veins should be cut is about 60 yds.

An adit has been driven along No. 3 for a distance of about 50 yds., proving the vein to a depth of 15 yds. from the surface. Where proved this vein is about 7 or 8 yds. wide and contains practically no lead-ore. This is about 100 yds. north of where it crosses the Dirty Rake. As it approaches the latter, it narrows down and nearly pinches out at the junction, but is not shifted, and it widens out again on the other side.

The vein contains a large amount of crystalline barytes, chiefly pink to brown in colour, and there is much chert. Some of the barytes seems to be moulded and grown on lumps of the chert, and this mixture fills the whole width of the vein. It is a good deal discoloured by ferruginous matter.

At this locality the crystalline barytes appears always to be associated with chert, and to occur in the N.W. and S.E. veins, while the caulk is principally found in the E. and W. Rake veins in which there is practically no chert. In all the veins there is some replacement of the walls by fluorspar or barytes.

In the White Rake, about a mile east of Wardlow, the gangue is mainly caulk, some pure white, while other parts are deeply stained with ferruginous matter. A little work has been done on the dumps along this vein.

The master vein of the Longstone Edge tract is known as the High Rake and the Deep Rake respectively in its west and east ranges. At its eastern end, about three quarters of a mile north of Great Longstone, fairly good barytes has been mined in an open working on the vein, where 4 ft. of solid barytes, chiefly boulder with a little caulk, can be seen. The whole width of the vein is not exposed. Galena is scattered in small bunches

through the spar. Both east and west of this point barytes is got from the old dumps.

The dumps of the Watershaw Rake, which runs east and west a quarter of a mile to the north of the High Rake, have been worked regularly for barytes during the past few years.

At the Sallet Hole Mine, in Combs Dale, the Deep Rake has been worked for lead-ore by means of a level, and a very large amount of mixed fluorspar and barytes has been got from the dumps. At this mine the Deep Rake is in many places 14 yds. in width.

The Longstone Edge district appears to contain a large reserve of barytes, as the main vein has never been worked systematically.

Sheldon, Youlgreave and Winster.

Maps.—One-inch New Series Ordnance, 111; Old Series Geological, 81 S.E.; six-inch Derbyshire, 23 and 28, Ord.

The Magshaw Rake, a mile south-east of Sheldon, yields barytes and a little fluorspar. The barytes is of poor quality, but occurs in abundance.

Further west the same vein, under the name of the Hard Rake, is worked for lead-ore at the Magpie Mines, but barytes is not abundant.

In the vicinity of Youlgreave and Alport some of the smaller veins contain a fair amount of caulk. The Long Rake, however, which is the master vein in this locality, contains lead-ore and fluorspar, but no barytes.

In the Winster and Elton district the dumps of the Portaway and other mines appear to contain much low grade barytes. The mineral also occurs sparingly in many veins in this area, and to the south-east on Winster and Bonsall Moor. Nearly all the dumps have been worked over for barytes, and the mineral carted to Via Gellia for treatment.

Brassington, Middleton and Wirksworth.

Maps.—One-inch New Series Ordnance, 111, 112, 124, 125; Old Series Geological, 81 S.E., 82 S.W., 72 N.E., 71 N.W.; New Series Geological, 112, 125.

Over a large part of this area there is a capping of dolomite on the limestone, and most of the barytes occurs in flats and pockets at or near the junction. Barytes, chiefly caulk, impregnates the whole area, but the proportion associated with fissure veins is comparatively small. It is noteworthy that the caulk occurring in the dolomite is usually more iron-stained than that in the limestone.

The Golconda Mine, Griff Grange, worked by the Hopton Mining Co., is situated 2 miles W. of Wirksworth and 1½ miles

S.W. of Middleton. It had been worked on a very small scale for some years before 1914; in 1916 extensive developments were undertaken.

There are two shafts, the Upper Golconda and the Golconda, the line from the one to the other being along the axis of an anticline pitching N.W. The workings are very irregular owing to the occurrence of the ore in pipes and flats. Much development is being done at a depth of 60 fms. on a large flat which locally attains a width of over 60 yds. There is a good deal of galena in the flat, especially in certain loose sandy patches. In places much hemimorphite occurs, but it seldom is associated with galena. The caulk is intergrown with the other minerals, and in some places with wad. The principal gangue mineral, however, is calcite.

The output since 1916 has averaged from 80 to 100 tons of dressed barytes per week. The mine is only 400 yds. from the High Peak Mineral Railway.

The Great Rake Mine, half a mile S.E. of Brassington, has been worked for caulk during the past few years by the Great Rake Mining Company, Brassington.

The mineral occurs in a well-defined fissure vein, the Great Rake, which courses a little N. of W. and underlies S. A vertical shaft 300 ft. deep cuts the vein at a depth of 175 ft., and the workings extend to a total depth of 400 ft. The chief gangue mineral is calcite, and there is some galena and wad. The vein varies in width from 2 to 5 ft. Much of the caulk occurs in the form of powder and grinds easily.

Transport to Longcliff Station, on the High Peak Mineral Railway, is by 1½ miles of poor road with very heavy inclines.

The Westerhead Mine near Longcliff is about three quarters of a mile N. of Brassington. It has been worked on a small scale during the past three years by the Brassington Barytes Co., Ltd., the total output from the mine amounting to a little over 500 tons. The mineral occurs in pockets and flats at or near the junction of the dolomite and the limestone.

The Bradwell Mines, half a mile E. of Middleton Cross, have been worked since 1915 by the English Barytes and Mining Co., Ltd. The workings are not on the main Bradwell Vein, but on a cross-vein running S.E. Some of the work was opencast, but at the south end the vein was opened up by shafts to a depth of 70 ft. The vein, which is from 3 to 5 ft. wide, contains both crystalline barytes and caulk. The brown crystalline lump barytes, containing from 95 to 97 per cent. of $BaSO_4$, was sold to disinfectant manufacturers. Between 1915 and 1920 there was an average output of 50 tons per week. In addition, about 50 tons per week of small barytes, averaging 80 per cent. of $BaSO_4$, were mined.

Crich.

Maps.—One-inch New Series Ordnance and Geological, 125; six-inch Derbyshire, 34 S.E.; 35 S.W., Ms.

15589. S 18/583. 1000. 1'22. C & R. LTD. 548.

In the Carboniferous Limestone at Wakebridge, about a mile N.W. of Crich, many veins have been worked for fluorspar by the Derbyshire Fluorspar Co., Ltd. A variable amount of barytes has been picked out from the fluorspar and sold. As sent away, it contains about 20 per cent. fluorspar. The barytes is chiefly a pinkish crystalline variety, but there is also a little caulk. The output of barytes during 1919–20 averaged 8 tons per week.

2.—Shropshire and the Welsh Border.

General Account.

The principal localities where barytes is worked in Shropshire and neighbourhood fall naturally into two districts, which differ geologically, and are separated by the ridge of the Stiperstones. To the west of this ridge lies the old lead mining region of Shelve, while to the east is the barytes field of the north-west portion of the Longmynd, where lead- and zinc-ores are almost unknown. (Plate VI.)

The Shelve area is occupied by Ordovician rocks. It is bounded on the east by Cambrian shales and the old rocks of the Longmynd, and on the other sides by the Silurian rocks.

The principal ore-bearing rocks are the Mytton Grits, of Arenig age, which are underlain by the Stiperstones Quartzite, and succeeded by the Hope Shales. The veins die out beyond the limits of the Mytton Grits.

The Mytton Grits are repeated by an anticline near Shelve, and extend over the Gravels mining field.

It may be taken as a general rule that veins ranging in an east-and-west direction carry barytes at the surface, and galena with blende in depth, while those with a northerly trend carry less barytes but more galena at the surface, as well as in depth.

In the mining region of the Longmynd the rocks are chiefly coarse, red and purple sandstones with subordinate, argillaceous and sandy shales of red and green colour. The veins range from a little south of east to north-east, and in those which have a north-easterly trend the barytes is stained with mineral oil, as in the high portions of some of the veins over the Stiperstones.

The other veins carry a pink variety of barytes which is never seen in the other Shropshire field. Traces of copper-ore occur, and copper glance has been worked at Westcott, near the Huglith Mine, and at Cothercott Hill, but the veins of this portion of the Longmynd may be regarded as essentially barytes veins, calcite and the other associated minerals being rather rare.

Both districts are served by the L.N.W. and G.W.R. joint-line from Shrewsbury to Minsterley. The Snailbeach Mine has a narrow-gauge railway to the Minsterley branch, and a similar line is being constructed for the Cothercott Company. The Shropshire Mines Company has an aerial ropeway from the Bog Mine to Minsterley and is contemplating the erection of another

one to serve the Huglith and Gatten Mines. From the other mines the mineral has to be transported over long distances by road.

Some of the barytes is sent away in the crude unground state after washing and picking at the mines, but most of it is treated and ground at mills in the district. The Cliff Dale Mill in the Hope Valley, near Minsterley, deals with the barytes from the Weston Mines belonging to the Cliff Dale Barytes Company. The Hanwood Mill, near Hanwood Station on the Minsterley branch, deals with the material from the mines belonging to the Shropshire Mines Company, while the Cothercott Company has a mill at the mine.*

Details of Mines.

The Mines West of the Stiperstones.

Bog Mine.

Shropshire Mines, Ltd., Minsterley.

Situated $4\frac{3}{4}$ miles S.S.W. of Minsterley, $\frac{3}{4}$ mile S.S.E. of Pennerley.

Maps.—One-inch New Series Ordnance, 165; Old Series Geological, 60 S.E.; six-inch Salop, 48 S.W., Ms., 55 N.W., Ms.

The veins shown on the Old Series one-inch Geological Map are no longer worked. They are known as the Main Vein and the North Vein, and mining operations, which extended to a depth of 1,200 ft., were concentrated mainly on their junction.

The workings are drained to a depth of about 350 ft. by the Boat Level. These veins do not carry barytes.

The southern extension of the Boat Level into the Nipstone Sett opened up a number of veins of which the most important are the No. 6, the No. 9, and the Nipstone Vein.

All these are now included in the Bog Sett, but only No. 9 has yielded barytes in commercial amount, and considerable quantities of good white material have been obtained. In depth the barytes is somewhat contaminated with disseminated galena.

No. 6 vein carries a small amount of barytes, while in the Nipstone Vein it is absent.

The average width of No. 9 vein is 5 ft., but in the main chute the barytes is over 12 ft. in width. The vein has been proved for approximately 250 ft. along the strike, and the depth of working up to 140 ft. below the Boat Level, and 655 ft. from the surface.

The old shaft, or Buntings Shaft, from which the Main and North Veins were worked, has been reopened, by the present Company, down to the Boat Level, a depth of 355 ft., and a new shaft, called Ramsden's Shaft, has been sunk 450 yds. further

* The mining-area has been mapped and reported upon recently by Mr. T. C. F. Hall, M.I.M.M., for the Shropshire Mines, Ltd. We are greatly indebted to the Directors of this company for the unrestricted use of his map and report, and for access to numerous plans and notes in their possession.

south to work the southern veins. At 400 ft. this reaches the Boat Level and a further sinking of 800 ft. is in contemplation.

The ore-bearing horizon is in the Mytton Grits, and the veins, which have an east-and-west trend, die out when followed beyond the limits of the grits.

The mine is connected to Minsterley, a distance of 6 miles, by aerial ropeway.

As a rule, the barytes is moderately soft and white with a granular structure. It is washed and hand-picked at the mine, the lump being separated from the smaller material. The latter is jigged and separated into fine lump, sand and waste. The lump is sent to Hanwood Mill for grinding, and is sold as best white. This mill deals with practically all the barytes raised by the company at their various mines, but an improved plant is being installed.

Calcot Mine.

(*Idle.*)

Cliff Dale Barytes Company, Ltd., Minsterley.

The mine is situated half a mile east of Priestweston, west of Corndon Hill and north of Llanfawr.

Maps.—One-inch New Series Ordnance, 165; Old Series Geological, 60 S.E.; six-inch Salop, 54 N.E., Ms.

This mine commenced in 1914, and was worked up to 1919, but has been abandoned on account of water troubles; it was worked in conjunction with the Weston Mine (p. 77).

The barytes vein courses E.N.E. through slaty rocks of Arenig age, and underlies north at about 75° from the horizontal. The thickness of the vein is 7 to 8 ft., but of this only about 15 in., lying on the foot-wall, is solid barytes, the rest being calcite with some bunches of barytes.

The barytes is white, of good quality, and, with the exception of a little iron, free from stains. Galena occurs in occasional spots and splashes, or more rarely in small bunches. Traces of copper-ores are rare, and quartz seldom occurs.

It is expected that the Calcot Lode, which lies to the south of the Weston Lode, will be cut by driving a crosscut from the new shaft at the Weston Mine.

Nick Knolls Mine.

(*Idle.*)

Shropshire Mines, Ltd., Minsterley.

Situated to the east of Hope Valley, 3½ miles S.W. of Minsterley.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 N.E.; six-inch Salop, 47 N.E., Ms.

Between 1872 and 1876 the barytes returns from this mine were approximately 60 tons per month.

The mine was given up on account of the influx of water from the Hope Valley Sett when the latter was closed.

The country-rock consists of the Mytton Grits. The Big or Nick Knolls Vein is the main lode; it gives off branches on the north, runs in a north-easterly direction along Nick Knolls and underlies steeply to the north-west.

The main shaft (on the south side of the vein) is about 300 ft. deep, and is stated to have cut a good lode at 150 ft.

The Big Vein attains a thickness of 8 or 9 ft., but is frequently "pinched" or "twitched." It consists chiefly of barytes, with some calcite and bunches of galena. The barytes is white, of good quality, rather tender, but little stained with iron, and normally not mixed with galena. Manganese dioxide in the form of dendritic markings covers some of the joints.

The principal offshoot from the Big Vein consists mainly of barytes about 2 ft. thick, but a rib of "sooty clay," 5 or 6 in. thick, forms the middle of the vein.

Pennerley Mine.

(Idle.)

Shropshire Mines, Ltd., Minsterley.

Situated at Pennerley, 4 miles S.S.W. of Minsterley.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 S.E.; six-inch Salop, 48 S.W., Ms.

This disused lead mine was worked to a depth of 1,080 ft., and was drained to 400 ft. by the Boat Level.

There are four important veins: the Ryder, running E.N.E., and three other parallel veins close together, known as the Big Ore, the Warm Water and the Red Vein, which range about N.N.E. Although the Ryder crosses the other veins, it does not appear to throw them off their course, nor to be influenced by them. The veins hade to the north-west, with the exception of the Ryder, which hades south-east, and traverse the Mytton Grits. The Ryder Vein is said to be underlain by a felspathic or a greenstone intrusion.

The extensive dumps contain a considerable quantity of zinc-ore. Calcite appears to have been one of the chief spars; quartz is also present and frequently replaces the other minerals.

In recent years the dumps have been worked over for barytes, and the little that is left is of remarkably fine quality, being either white or almost transparent. There is also a little of the dark variety, stained with mineral oil.

Perkinsbeach Mine.

Shropshire Mines, Ltd., Minsterley.

Situated in Perkinsbatch, $3\frac{3}{4}$ miles south of Minsterley.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 S.E.; six-inch Salop, 48 S.W., Ms.

The Perkinsbeach Mine has been worked intermittently for many years (above 70 years according to an old workman), but not until recently for barytes.

The country-rock consists of the Mytton Grits.

Operations here are on the Big Spar Vein which runs in an E.N.E. direction on the south side of the road under Green Hill.

The vein underlies slightly to the south-east. Its maximum width is 8 yds., but of this there is seldom more than 6 ft. of spar, and usually less.

It has been reopened above adit level. Barytes is practically the only constituent. Bunches of galena occur in places, but blende is not met with. Calcite is less common than in other veins. Dark barytes, with hydrocarbon staining, is abundant, and a certain amount of white spar of fair quality is present.

There is an output of about 40 to 50 tons per week. A great obstacle to working at certain seasons is the heavy water in the lower parts of the mine.

Rhadley Mine.

(*Idle.*)

Shropshire Mines, Ltd., Minsterley.

Situated on Black Rhadley Hill, 4½ miles N.N.E. of Bishop's Castle.

Maps.—One-inch New Series Ordnance, 165; Old Series Geological, 60 S.E.; six-inch Salop, 54 N.E., Ms.

This mine has been disused for some years.

Barytes occurs in an east-and-west vein running through the Stiperstones Quartzite and the Mytton Grits. The vein is from 2 to 8 ft. in width, and apart from barytes contains only a little calcite with specks of galena. The spar is of good quality with merely superficial iron-stains.

A quantity of barytes has been extracted from open-cast workings on the top of the hill, and a shaft has been sunk there on the vein. About 250 ft. below, near the road on the north-west of Rhadley, an adit level was driven into the hill with the intention of exploring the country-rock and of joining up with the Boat Level so as to unwater the southern part of the mine-field. It was driven for several hundred yards, but met with mere strings and pockets in shaly ground, from which it would appear that the Rhadley Hill Vein has pinched out in depth.

The Rock Mine.

(*Idle.*)

Shropshire Mines, Ltd., Minsterley.

Situated half a mile N.E. of Black Rhadley Hill and 2¼ miles N.W. of Norbury.

Maps.—One-inch New Series Ordnance, 165; Old Series Geological, 60 S.E.; six-inch Salop, 55 N.W., Ms.

The mine ceased working for lead-ore many years ago, but has been worked recently on a small scale for barytes.

There are two veins, the main vein ranging north and south, and a cross vein east and west. The latter runs for a third of a mile from the Stiperstones Quartzite at the Rock through Mytton Grits into the Hope Shales on the west. It appears to be 2 to 3 ft. in width. There is apparently a quantity of galena, not only in the vein-stuff, but also in strings and crystals scattered abundantly in the quartzite near the vein, and this fact, added to the absence of true leaders through the "pinches," makes the vein difficult to follow.

The little barytes in the dumps is in "lump" mixed with "deads," but is of good quality. Some barytes sand is present in the old lead-washings.

On the side of the Rock a shaft 120 ft. deep was sunk on the main vein, and has been worked for lead and barytes.

Round Hill Mine.

(*Idle.*)

Shropshire Mines, Ltd., Minsterley.

Situated at the south end of Buxton Hill, a third of a mile west of the Tankerville Mine, and about $3\frac{3}{4}$ miles S.W. of Minsterley.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 S.E.; six-inch Salop, 48 S.W., Ms.

The mine has been abandoned for many years, but recently the dumps have been picked over.

The mineral vein traverses the slaty rocks of Arenig age in a direction about N.W. by S.E., and (as may be judged from the fragments on the dumps) runs into the igneous mass which forms Buxton Hill. It is said to be 6 or 7 ft. wide, and has a fairly steep westerly underlie.

The vein was worked from a shaft, situated near the cottages on the west side of the south end of Buxton Hill and north-west of Round Hill. It is said to be about 130 yds. deep, but is now almost full of water.

The minerals include galena, blende, calcite and barytes, with a little quartz and minute crystals of pyrites. The barytes is good white, but largely mixed with calcite.

Rorrington Mine.

(*Idle.*)

Shropshire Mines, Ltd., Minsterley.

Situated at Rorrington Hill Covert, half a mile S.E. of Rorrington and the same distance N.E. of Middleton.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 S.E.; six-inch Salop, 47 S.E., Ms.

There are said to be three lodes running east and west, which carry lead-ore at the top of the hill and barytes in depth, thus forming an exception to the general rule of the district, that veins with an east and west trend carry barytes on top and galena and blende in depth. The main vein, underlies south, is 7 ft. thick, and carries barytes mixed with calcite. All the lodes are in the Lower Llandeilo beds (Weston Group).

The dumps contain a good deal of barytes and calcite. Much of the barytes appears to be good white spar, but inside is stained green. Some of it contains crystals and nests of galena.

This mine produced 347 tons of barytes between the years 1889 and 1893. It was reopened by the present company in July 1919. The deep adit level and two old shafts were opened up and a little stoping done, producing 16 tons of barytes. The mine was closed again in July 1920.

Snailbeach Mine.

Halvans, Ltd., Engineer's Office, Ruabon.

Situated 1¾ miles south of Minsterley.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 N.E.; six-inch Salop, 48 N.W., Ms.

The veins were originally worked for lead-ore. A pig of lead, now preserved in the British Museum, was discovered here which bears the inscription of the Emperor Hadrian (A.D. 117–138).*

Plans of mines at this locality, dated 1790, are in existence. At an earlier date, probably the 12th and 13th centuries, the "old men" must have been at work, for many of their workings have been met with while opening up for barytes, and much lead-ore was obtained. Up to a few years ago, galena and blende were worked as well as barytes, and the vein was then proved to a depth of 552 yds. below the surface. Barytes has been got in some quantity during the last 20 years.

The lode is being worked on a small scale from the Perkins Level at the top end of the dingle. Rises are put up from the level and the ground stoped out partly by hand and partly by blasting, but no rock-drills are in operation. The material is sent down shoots to the level and trammed out to the picking floor. The deepest work is now on the 40-yd. level.

The main vein runs practically east and west through the Mytton Beds. The average thickness is about 8 ft., but the vein is subject to "swells" and "pinches" or "twitches." In the former it sometimes attains a width of nearly 40 ft., and in the lowest workings was frequently 22 ft. across. This main lode is known as the Snailbeach Vein and is underlain by a smaller or "back" vein, which is seen to the north of Tom Shaft in one of the "old men's" workings. This vein is from 3 to 4 ft. thick, and sometimes cuts across and unites with the Snailbeach

* G. H. Morton, "The Geology and Mineral Veins of the country around Shelve, Shropshire." *Proc. Liverpool Geol. Soc.*, 1868–9.

Vein, as in the workings near the Tom Shaft and in the Perkins Level. Here the junction gives rise to the exceptional thickness mentioned above. The Snailbeach Vein dips about 60° S., but at the surface near the Tom Shaft it is almost vertical and continues so in the shaft for about 40 yds. Between the 40- and 80-yd. levels the "back" vein is believed to come in, and the main vein flattens considerably.

The bulk of the vein-stuff is barytes, but strings and pockets of witherite and calcite occur along with galena, blende and traces of copper pyrites and iron pyrites. The witherite occurs in spherical masses with a radiate structure, but it is not abundant. Recently, 20 tons were sold.

Calcite occurs in abundance, and is taken from the dumps, screened and washed, after which it is sold for the "rough-casting" of walls, concreting, and gravelling of paths. Most of it is white, but pale amethystine and wine-yellow varieties also occur.

Galena and blende, the chief ores met with in the veins, occur in pockets and strings in the barytes. Near the surface the barytes is practically free from them, but lower down, galena becomes commoner, and is in turn, at a still greater depth, partly replaced by blende, which is said to occur most frequently below the 400-yd. level.

The barium minerals are of two qualities: the best white, which is slightly coloured, and a dark grade, more or less stained with mineral oil, which oozes from geodes or cavities in the veins. The dark variety predominates in the higher portions of the vein, and although strongly stained with hydrocarbon, assays above 99 per cent. of barium sulphate. The staining is not detrimental in this case as the material is not used in paint.

The barytes is washed over a grating in the usual way and hand picked, the smaller material is separated from galena, calcite, &c., in jigs worked by a steam engine. No grinding or milling is done at the mine.

The minerals are carried on a narrow-gauge railway to the Minsterley branch of the Great Western and London and North-Western Joint Railway, near Pontesbury, a distance of about 3 miles.

Tankerville Mine (formerly known as "The Ovenpipe").

(Idle.)

Shropshire Mines, Ltd., Minsterley.

Situated near Pennerley, 3½ miles S.S.W. of Minsterley.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 S.E.; 6-inch Salop, 48 S.W., Ms.

This mine was worked for lead-ore, but has been abandoned for many years.

There are four veins in the Mytton Beds known as the Tankerville, the North and South Lodes and the Old Lode, respectively.

The extensive dumps contain a large amount of calcite and a good deal of barytes. They are dug for "rough-casting" walls, but do not appear to have been overhauled for barytes. The barytes is white and of good quality; granular, platy, and crystalline varieties are present, all fairly free from impurities. No dark barytes was noticed, possibly through the ores having been obtained from depth.

Weston or Cliff Dale Mine.

Cliff Dale Barytes Company, Ltd., Minsterley.

Situated north of Corndon Hill, ¾ mile east of Priestweston.

Maps.—One-inch New Series Ordnance, 165; Old Series Geological, 60 S.E.; six-inch Salop, 47 S.E., Ms.

This mine is said to have been worked intermittently for barytes for 50 years.

The vein runs east and west through the ridge of rocks consisting of greenstone and felspathic ash, of Arenig age, which lies between the Shelve Hills and Marrington Dingle. The Weston Vein is believed to be a continuation of the White Grit Lode, which was worked to the east in the valley, but in this direction in the mine levels, the lode dies out so far as practical mining is concerned, and is represented by a hard breccia with thin strings of barytes and calcite. This breccia comes on after the lode has passed through some twenty-feet of black shales which, near the lode, are splashed with small flakes of galena. In a crosscut on the east, these shales are traversed by a sill of greenstone, about 15 in. thick.

The vein underlies south at about 60° to 70° from the horizontal but flattens and "rears" considerably. It has been noted that where the lode is steeper there is less calcite than in the flatter portions. It averages three feet in thickness, but in places "twitches" down to a few inches, and in others swells up to eight feet. In the "twitches" lead-ore is occasionally met with in bunches. As a rule, where the lode flattens it is narrowest. There are 6 levels worked from the present shaft, the lowest being at 75 fms. The vein shows no sign of deteriorating in depth.

At the east end of the 75-fm. level the lode turns slightly north and shows much lead-ore.

At the east end of the 65-fm. level the vein is siliceous and much brecciated, while at its western end there is a seam of good barytes six feet wide.

A new shaft is being sunk to the south of the lode to cut it at a depth of about 100 fms. In this shaft at 50 fms. a hitherto unknown lode was struck, consisting of calcite, galena, blende and barytes.

Over the greater part of the mine the vein consists almost entirely of barytes. Calcite, as a rule, is confined to a few inches or less on the walls, but in places occupies the vein, except for occasional bunches, to the exclusion of barytes.

The barytes is of good quality, white, with little iron-staining, and is usually fairly soft and more or less granular in texture.

Water is pumped from the lower levels to an adit at 35 fms. depth.

The minerals are picked and washed over a grating. The small material which passes through the grate, is hand-jigged to get rid of calcite and the finest material is slimed as a third mine-grade.

The barytes is separated into three grades and sent to the Cliff Dale Mill, in the Hope Valley, near Minsterley, owned by the same company.

First-grade lump and small lump are good white, and but slightly iron-stained. Second-grade coarse sand and fine gravel are practically the same quality as first-grade and contain little vein-filling. Third grade is the sand from the slimes and contains a certain amount of fine country-rock and vein-filling, but sometimes makes a second quality " flour " after milling.

Steam wagons are used to convey the barytes from the mine to the mill, a distance of 5½ miles.

At the mill the barytes is broken up to a coarse sand, bleached and ground fine.

Wotherton Mine.

(Idle.)

Shropshire Mines, Ltd., Minsterley.

Situated at Wotherton, 1¾ miles N.E. of Chirbury.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 N.E.; six-inch Salop, 47 N.W., S.W., Ms.

This mine was worked for about 40 years for barytes. The vein was proved down to 286 yds., but deteriorated in depth; for, although it was 16 ft. across in the bottom working, it contained mostly calcite, with barytes only in bunches ½ yd. to 2 ft. wide. The same change was observed in a westward direction.

Owing to the low situation, water caused difficulty, and an 8-in. plunger with a 4-ft. stroke was installed to deal with it, but in depth, with an increase of water and a decrease in percentage of barytes in the vein, the cost became prohibitive.

The barytes vein runs approximately east and west, on the east through beds of Bala age and on the west through Wenlock Shale. The underlie, which is fairly steep, is to the north. The width of the vein averaged 15 ft., but it frequently reached 16 to 20 ft. This, however, included a good deal of calcite. Apart from calcite the vein was exceptionally free from other minerals; occasional spots of galena and, more rarely, blende being present.

The barytes obtained was pure white, free from iron-staining and reported to be the finest quality found in England.

At one time all the material was crushed and ground on the mine premises, but later the mill was removed to Hanwood.

All the barytes was pure white, and at the Hanwood Mills was ground without bleaching or further treatment, some carbonate of lime consequently being left in the finished product.

A flow of inflammable gas, and a hot saline spring have been reported as occurring in the lower workings.

The Mines East of the Stiperstones.

Cothercott Mine.

Cothercott Company, Ltd., Dogpole, Shrewsbury.

Situated on Cothercott Hill (Wilderley Estate), Castle Pulverbatch, nine miles south by east of Shrewsbury.

Maps.—One-inch New Series Ordnance, 152; Old Series Geological, 61 N.W.; six-inch Salop, 48 N.E., S.E., Ord.

The principal barytes vein runs west by south to east by north, through purple and green sandstones and shales of Longmyndian age, and underlies north at about 60° from the horizontal.

Two counter lodes split off on the north side of the main vein and underlie south.

The main vein averages in thickness about 5½ ft., but it narrows down to a foot or less and expands up to 12 ft. or more at intervals.

These expansions are regular in character, and appear to be in the nature of swellings along certain beds in the country-rock which dips with them in a westerly direction.

The vein is at present worked on the northern slope of the hill, from two adits, Nos. 8 and 9. From these adits levels are driven along the vein.

An expansion of the vein in the lower level corresponds with one further to the east in the higher level, and several of these expansions have already been cut. In the lower level a shaft has been sunk to a depth of 40 ft., where the barytes is of better quality; the vein is six feet wide as compared with only 4 ft. in the level.

The vein is said to have been traced at the surface for over 2 miles.

A shaft is to be sunk on the north side of the vein near the mill.

There are many indications of barytes to the south of the main vein, and especially in the hill area. They are to be found in every direction, showing good barytes at the surface, but have not been fully explored. The total area of the estate is 3,500 acres.

The barytes is remarkable for its purity and softness. It is entirely free from lime and other spar, and the crude material

assays 99·7 per cent. of $BaSO_4$. It is of the pink variety characteristic of the Longmyndian, but in the centre of the big expansions white barytes is often found.

No mineral oil has been found, and calcite, quartz and galena are unknown. The barytes is consequently of the finest quality except for the pink colour, which defect the company expects to eradicate by a new method of treatment.

The barytes, with the exception of the poorer grade from the "twitches," which is sold crude, is treated at the company's mill at the mine, to which a tramway has been laid round the hill from the levels. It is being extended from the mine works to connect with the Great Western Railway's main line near Dorrington, a distance of about 4 miles.

At these works, in addition to two other mills, there are 4 pairs of French buhr stones, while 6 more are being installed, and there is also a new bleaching plant. Owing to its unusual softness, the passage through a single pair of stones is generally sufficient to bring the barytes to the required state of fineness. It is subsequently graded automatically to a minimum 350-mesh standard product.

When the mill extension is completed an output of 200 tons weekly of the finished product will be possible. The company intends to manufacture all classes of barium products.

With extended development, the mine is expected to produce about 50,000 tons per annum.

Gatten Mine.

Shropshire Mines, Ltd., Minsterley.

Situated near Gatten Lodge; about 4¼ miles S.S.W. of Pontesbury.

Maps.—One-inch New Series Ordnance, 152; Old Series Geological, 61 S.W.; six-inch Salop, 48 S.W., Ms.

The barytes lode courses E.S.E. to W.N.W. It inclines in a northerly direction at about 60° from the horizontal at the surface, and at about 70° in the bottom level. The country-rock consists of the Longmyndian beds. The walls are good, except in the "twitches," where they are usually soft. In places the hanging-wall is composed of hard granular quartz; in others it is rather broken, and the barytes near it is mixed with clay. The foot-wall is solid and frequently slickensided.

The vein averages about six feet in thickness, but is "bunchy." It pinches locally to a foot or eighteen inches and swells up to twelve feet. Near one of the big bunches a split is given off to the south.

The gangue, except for an occasional small rib of stone near the middle, consists entirely of pink barytes characteristic of the pre-Cambrian rocks, with a little mineral pitch on the hanging-wall at the crop.

In 1921 the mine was being developed. A shaft has been sunk 170 ft. below surface, and a steam winding-engine erected.

Levels are being driven east and west from the bottom of the shaft. There the vein is only about twenty inches wide, but shows signs of increase.

The barytes is hand-picked before being carted direct to Pontesbury, a distance of five miles.

Huglith Mine.

Shropshire Mines, Ltd., Minsterley

Situated 2¾ miles south by east of Pontesbury.

Maps.—One-inch New Series Ordnance, 152; Old Series Geological, 61 N.W.; six-inch Salop, 48 N.E., Ord.

This property includes two mines known as Huglith No. 1 and Huglith No. 2. The latter is now abandoned, as the vein disappeared at 80 ft. below the surface.

No. 1, which is adjacent to the old Westcott copper mine, is being developed, and a shaft has been sunk to 165 feet below adit level. The vein which has been proved underground for a length of about 400 ft., has yielded two rich chutes of ore up to 20 ft. in width, with an average width of about seven feet.

The barytes vein, which is in the Longmyndian grits, ranges approximately east and west and underlies south at about 70° from the horizontal.

The barytes varies in colour and in hardness; the greater part of it is pink, with some deep pink to red, it is usually hard, but a small proportion of white, which can be separated by hand, is washed, hand-jigged and sent to Hanwood Mills for treatment. The remainder, which is washed and picked, is sold crude.

Calcite and quartz occur commonly with the barytes, and the vein is sometimes split up by ribs of rock. A small amount of copper glance with associated malachite and azurite is sometimes present, particularly in the more rocky parts of the vein.

No trouble has been experienced as yet with water, and the mine is regarded as dry. Ample water for washing, &c., is raised by a ram from the brook below the mine.

Transport from the mine is effected by a tramway to a small loading place by the road, whence the spar is sent by road to Pontesbury a little over 3 miles distant. An aerial ropeway is to be erected by the company.

To the south of the mine the hillside has been extensively trenched in search of minerals in the red sandstone country-rock, and at least three barytes veins have been met with. These all trend east and west and underlie north.

Wrentnall Mine.

Wrentnall Baryta Company, Ltd.

Situated at Broom Hill, one mile west of Church Pulverbatch.

Maps.—One-inch New Series Ordnance, 152: Old Series Geological, 61 N.W.; six-inch Salop, 48 N.E., Ord.

This mine has been in operation for about thirteen years, and for the last five under the present company.

There are several veins of barytes all ranging in a north-easterly direction. The country-rock consists of the reddish-purple sandstones of Longmyndian age, which are overlain by the Coal Measures about one mile to the east. Some of the workings are on the north side of the stream and others on the south; these are described separately.

Three veins on the south have been worked, which meet and form a pocket at their eastern end. The main vein ranges N.E. to S.W., and is approximately vertical. In the workings close to the road between Castle Pulverbatch and Habberley the thickness of the vein is about 9 ft. The veins are almost worked out above water-level and preparations are being made for sinking on a new pocket underlying south and averaging about 6 ft. in width and thirty yards in length.

A short distance to the south-east of the opencast on the top of the hill, a parallel vein, consisting entirely of barytes, and about 8 ft. thick, has a slight hade to the south-east and has been worked, but it dies out in depth and is not found in the level at about 85 ft.

The main vein, on the north side of the stream, with splits of almost equal thickness, has been worked in the valley and has been traced to near the road by Wrentnall House. It has an average thickness of about 4 ft., but both it and the offshoots from it are subject to "swells," sometimes 13 ft. across, which contain rich deposits.

Work was suspended for a time owing to a large admixture, at a depth of 20 yds., of white sand with the barytes, but is now proceeding at a lower level, about 15 ft. above stream level, where the vein is richer, and underlies south.

The barytes is mostly of the dark type, though some of it is slightly pink internally. Lead-ore is seen occasionally, and usually near the surface. Malachite and azurite stains appear in places, and lumps of mineral pitch are found.*

About 40 men are now employed and the material is treated at the mine. The best lump is picked out, the rest is crushed to a maximum of one inch, then jigged to remove refuse, and automatically graded. The dark hydrocarbon stains are not detrimental as a pure white product is not required.

The barytes is carted about 3 miles to Plealey Road Station, on the Minsterley branch.

Bulthy Mine.

English Barytes and Mining Company, Ltd., Derby.

Situated two-thirds of a mile north-east of Middletown, and 6 miles N.E. of Welshpool.

* A specimen of bitumen from the bottom of the sump has been presented to the Museum of Practical Geology. It is two feet wide and encloses crystals of quartz which formerly lined the walls of the vein.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 N.E.; six-inch Salop, 32 N.E., Ord.

This mine is one of those believed to have been worked for lead-ore by the Romans. Barytes was continuously sent away from it between 1881 and 1894, the average output being about 420 tons a year, with a maximum of 1,100 tons in 1893. After 1894 no mining was done, but in 1913 the dumps were turned over and 106 tons of good quality lump spar obtained. During the war period the adit level was opened up and the vein was also worked by open cast, a total of about 2,700 tons of barytes being abstracted.

The barytes occurs in two veins ranging N.W. to S.E., in the shales, sandstones, ashes and conglomerates of Bala age.

The main vein has been followed in a N.W. to S.E. direction for about 1,300 yds., and varies in width from four to eight feet.

An adit level has been driven 614 yds. into the vein along the south side of Middletown Hill.

The barytes is principally the darker variety, though in places pure white crystalline spar has been obtained, yielding 99·7 per cent. of barium sulphate.

All the barytes is sent away crude after hand picking and grading into best white and a lower quality of dark stained spar.

A tramway round the hill takes the material to a loading place by the main road, whence it is carted to Middletown Station, about 1½ miles away.

CHAPTER IV.

THE MINES OF WALES AND THE WEST OF ENGLAND.

1.—North Wales.

General Account.

Barytes and witherite have been regularly obtained during the past eight years at the Pennant Mine, near St. Asaph (Plate VI.). Much of the material has been collected from the extensive spoil-heaps, but recently the spars which occur in an east-and-west lead- and zinc-bearing vein in the Wenlock Shales have been mined. Within the past three years the barytes occurring in veins in the Carboniferous Limestone, and Silurian flags and shales, has been mined also near Ruthin and Llangollen. The output has been small.

Barytes is frequently abundant in the lead mines of the Llangynog district, but not much work has been done in this district owing to difficulties of transport.

A small mine in the Lleyn peninsula, which formerly worked barytes, has been closed for the past two years.

Details of Mines.

Pennant Mine.

St. Asaph Zinc, Lead and Baryta Company, Ltd.,
Eldon Street House, London, E.C.

The mine is near the village of Rhuallt, on the main road to Holywell, and three miles east of St. Asaph.

Maps.—One-inch New Series Ordnance, 107; Old Series Geological, 79 S.W.; six-inch Flintshire, 5 S.W., Ms.

This is an old lead-mine which has been working intermittently, probably since Roman times. As a lead mine its activity ceased in 1891. In 1913 it was reopened under new management, mainly for barytes and witherite, which form the predominant spar constituents of the extensive dumps.

The principal vein courses east and west, with a slight inclination south, through the Wenlock Shales. The workings extend along the vein for about 500 yds., but the course of the lode can be traced for upwards of a mile. Westwards it is lost under Glacial drift, though it probably does not extend beyond the great boundary fault at Brynllithrig Hall. An unsuccessful trial was made 450 yds. east of the third milestone from St. Asaph, to trace the eastern course of the vein along the south side of the stream. There are indications of branches of the main vein near the old workings.

The main vein, from 9 to 10 ft. wide, carries galena in the centre, and smaller quantities in the surrounding gangue,

which consists mainly of barytes and witherite. Zinc-blende, in aggregates of many sizes, also occurs scattered through the vein. The barytes, in places, forms a solid mass, 6 ft. wide, and is clearest on the east, where the vein is in proximity to the Carboniferous Limestone. Witherite, frequently abundant in large pockets, occurs either as white crystalline radiating masses, or in the greyish-black crystalline form. Both are of good quality.

The present actual working depth is 270 ft., the old workings below that depth down to 360 ft. not having been fully opened out.

There are three shafts and a day-level, through all four of which the ore is brought out. The principal shaft, the New Engine Shaft, is 180 yds. south-east of Pennant House. A steam pump has been installed to unwater the deeper levels, which are partially drained by the old day-level, or the 40-yd. level, in the mine. The entrance to this level is alongside the main road, sixty yards south of Pennant House.

The refuse-heaps are extensive, and contain much zinc-blende, barytes, and witherite. They are half a mile in length, and about 100 ft. wide, and are considered to have a total content exceeding 100,000 tons. In many places they are being worked over for barium minerals, which constitute the principal spar constituents, and for the little galena that remains.

A grinding mill and dressing plant, driven by oil, commenced work in the autumn of 1919. The first jig removes the gangue from the barytes, or witherite and galena, and these are afterwards separated by hand-jigging. A simple plant has been devised for separating the blende from the crystalline barium compounds by a process of decrepitation. By heating on iron plates to a low red heat of not more than 400° C. the crystalline barytes decrepitates to a fine powder, and can then readily be separated. Aluminium plates have been tried in place of the iron ones, and neither have proved an unqualified success. A silica-lined furnace would perhaps be more successful. In addition to removing the blende, this method also purifies the barytes, and leaves it in a suitable condition for a primary grinding which is effected in a mill fitted with French buhr stones.

Plenty of water is available from the neighbouring streams, except in dry summers.

Three grades of witherite have been produced in the past, but owing to lack of demand for low-grade material, only hand-picked lump is now being sent away. The highest grade is a small hand-picked lump, and the second is in the condition of gravel. The lowest grade is got by picking out all spar rich in metallic ores, which are separated by crushing and jigging. The non-metallic residue is a low-grade witherite sand with a considerable admixture of barytes and fragments of country-rock. The barytes output is largely conditional on relative demand. Two grades are produced (1) crude lump and (2) fine-grained material. When the demand was considerable the barytes output attained about twenty tons a week.

The barium minerals are sold chiefly to home manufacturers of paint and pigment, and a certain amount is exported.

Witherite has been mined for the last forty years; in 1875 about 85 tons were obtained, while the average yearly output until 1891 ranged from 200 to 300 tons. None was produced between 1891 and 1913, but the mine was reopened in 1913 and about 100 tons of barium minerals, mainly witherite with some barytes, was obtained. The output for the past few years has been slightly less, amounting to 68 tons in 1919.

Eyarth Mine

Ruthin Mines Company, 302, Royal Liver Buildings, Liverpool.

The mine lies on the western side of the Ruthin-Corwen main road, $1\frac{3}{4}$ miles south of Ruthin, and 600 yds. due west of Eyarth Station.

Maps—One-inch New Series Ordnance, 121; Old Series Geological, 74 N.E.; six-inch Denbighshire, 19 S.E., Ms.

The Carboniferous Limestone which forms a bold escarpment, extending from the west of Ruthin southwards to Llanelidan, has a prevalent easterly dip, and is overlain by the Triassic sandstones of the Vale of Clwyd.

At Bron-eyarth, and to the east of Efenechtyd, two intersecting, east-and-west veins carrying barytes, have been mined intermittently by means of open-cast workings.

These veins, have been traced from a point 160 yds. south of Ty'n-yr-onen, eastwards past Bron-eyarth Farm to the Ruthin-Corwen main road, a total distance of 1,200 yds.

The two branches, about 40 yds. apart on the Ruthin-Corwen main road, have both been worked. They both hade slightly to the north, and appear to unite near the summit of the hill. A day-level, 180 yds. due east of Bron-eyarth Farm, has been carried for 40 yds. along the more northerly lode, which consists of a series of lenses or swells, the average width of 3 ft. being all solid barytes.

Along the more southerly vein, an inclined drift was driven, about 120 yds. east of Bron-eyarth Farm, but was abandoned owing to water trouble.

The barytes is crystalline in form and of a slight pink tinge. It is sold in lump form, after being hand-picked.

Since 1918 about 100 tons of barytes have been sent away. Twenty years ago these veins were opened out in open-cast workings, 600 yds. due east of Efenechtyd Church; and about 40 tons of barytes were sold in 1902, but no further work has been done on them.

Llangynhafal.

At Llangynhafal, 3 miles north of Ruthin, and on the eastern side of the Vale of Clwyd, barytes is abundant along the course of a north and south fault between the Carboniferous Limestone

and the Wenlock Shales, but has never been worked. It is most abundant near the farms Tyddyn-deddwyd, and Bryn-Cirion.

Ty'n-y-celyn Mine.

Llangollen Mines Company, Ltd., 302, Royal Liver Buildings, Liverpool.

The Mine is alongside Ty'n-y-celyn Farm, 1,000 yds. east of Pengwern Hall ; and 1½ miles south-east of Llangollen.

Maps.—One-inch New Series Ordnance, 121; Old Series Geological, 74 N.E.; six-inch Denbighshire, 39 N.E., Ord.

On the steep northern slopes of Craig-y-dduallt, barytes is the predominant constituent of two nearly vertical veins which traverse the Ludlow flags and shales. The West Vein follows a north-north-east direction while the East Vein, 70 yds. to the east of the former, trends nearly north and south.

The West Vein is well seen on the slopes of the hill about 100 yds. south-east of Ty'n-y-celyn Farm.

The veins have been traced on the surface, by means of old open-cast workings, over a horizontal distance of 300 to 400 yds. They may extend much further in a southerly direction, but to the north where they appear to converge, the strata are much disturbed, presumably by a powerful east-and-west fault.

The lodes were first worked for barytes in 1918. From a point 40 yds. due south of Ty'n-y-celyn Farm, a crosscut has been driven for a distance of 88 yards in a south-easterly direction, and enters a working level in the West Vein, about 50 yds. below the surface. The level in the West Vein has been driven for a distance of 66 yds. in a northerly direction, and the barytes has been mined over this area.

The lode has prominent "leaders" or definite north-and-south cheeks, and a slight hade north. It varies in width considerably as it consists of a series of lenses or swells, its average thickness being about 3 ft. It contains almost exclusively white highly crystalline barytes, with only traces of galena.

The East Vein has not yet been opened up, except in old open-cast workings, but the main crosscut which has been driven for 40 yds. east of the West Vein, is intended to intersect it.

The barytes is hand-picked before being sold. Hand-jigging has been tried to clean the remainder but without much success.

The output has been less than 100 tons.

There is a good road from the mine to Llangollen Station (G.W.R.), a distance of about 1½ miles.

Pompren Barytes Mine.

(Idle.)

Lleyn Mines, Ltd., 22, Basinghall Street, E.C. 2.

Situated at the mouth of a stream, Afon Saint, 3 furlongs west of Aberdaron.

Maps.—One-inch New Series Ordnance, 133; Old Series Geological, 76; six-inch Carnarvonshire, 43 S.E., Ord.

The barytes occurs in a fault, which brings Ordovician slates against more ancient schists. The lode is ten feet wide, but is composed of a number of intersecting stringers of quartz and barytes, running generally north and south, the maximum width of any one stringer being rarely over a foot. The barytes occurs in pockets, which are more or less free from quartz and of good quality, but they are infrequent and small. Other parts of the stringers contain about equal quantities of quartz and barytes, which are intergrown.

The vein runs approximately north and south, with a slight underlie to the east. Its walls are not well defined as the barytes forms a cement to country-rock brecciated by the fault.

The method of working was partly by open-cast and partly by levels driven along the lode. The dressing plant, situated immediately above high-water mark in the mouth of the valley, was worked by water-power. A small pier which was erected to facilitate transport by sea is still intact.

2.—Central and South Wales.

General Account.

Barytes veins are found in the Lower Palæozoic rocks of Central Wales, around Llanidloes, where they carry witherite; in South Wales near Carmarthen, and near Bridgend where they lie in the Carboniferous Limestone, the Lias and the Rhaetic (Plate VI.). All these veins carry small amounts of galena and other metallic ores, for which some of them were worked in the past. Attention may be called to the Carmarthen Mines, as their products can be shipped directly.

Details of Mines.

Llangynog District.

Maps.—One-inch New Series Ordnance, 136; Old Series Geological, 74 S.W., six-inch Montgomeryshire, 4 N.E., S.E.; 5 N.W., Ord.

The Llangynog mines are situated about a third of a mile south of Llangynog Station (6-in. Montgomeryshire, 4 S.E.). They were worked intermittently for lead- and zinc-ores in the 19th century, but closed in 1887. An east-and-west fault with Llandeilo slates and shales on its south, and rhyolite and associated lavas on its north side, is filled with quartz containing abundant galena and blende, and smaller quantities of copper pyrites. Barytes and witherite also occur, but sparingly.

The Cwm Orog mines, (six-inch Montgomeryshire, 4 N.E.) are on the east side of the Bala road, $\frac{3}{4}$ mile north-west of Llangynog. The vein, which trends slightly north of east lies principally in

igneous rocks. There are four day-levels. A vein, 2 to 3 ft. wide, of good quality barytes with some witherite occurs in the lowest working. The spar is free from staining and impurities.

These mines were worked during the last century for lead ore, and were reopened for a short time 15 years ago.

Craig Rhiwarth mines (six-inch Montgomeryshire, 4 N.E.) are about 900 yds. to the east of the Cwm Orog workings. The same vein as that seen at Cwm Orog was last worked about 30 years ago for the ores of lead, zinc, and copper. The vein is about 3 yds. wide, and carries brownish-yellow barytes, and witherite, which are abundant on the old spoil-heaps. The country-rock is a porphyritic igneous mass.

Craig-y-mwyn mine (six-inch Montgomeryshire, 5 N.W.) is on the western side of the Rhaiadr valley, 3½ miles north-west from Llanrhaiadr Station. There are four lodes running east and west; a fifth, W.N.W. and E.S.E.; and a sixth, north and south. The veins lie in faults which frequently throw slate against igneous rock. The numerous lodes are intersected by two levels, one of which is 300 yds. long. The mine was opened for lead-ore in 1769, and was worked intermittently until it was abandoned about 1911. Barytes and witherite occur, but, it is said, not in workable quantity.

Bwlch Creolan mine (six-inch Montgomeryshire, 4 S.E.) is situated 4½ miles south-east of Llangynog. A prominent N.W. and S.E. vein traversing Bala sandstones and shales carries galena and barytes. The latter is seen in some abundance along its course, but whether it exists in workable quantity is not known.

Bryn-y-Tail Mine.

Ryland Barytes and Silica Company, Ltd.

Situated 3 miles W.N.W. from Llanidloes.

Maps.—One-inch New Series Ordnance, 164; Old Series Geological, 60 S.W.; six-inch Montgomeryshire, 41 S.E., Ord.

This mine was worked for barytes some 50 years ago, it is said, by a German firm. The buildings are now in ruins, but there are the remains of several large stone tanks and a grinding mill. Two small leats, an upper and a lower, carried a supply of water from the Clywedog River.

The present company reopened the mine by an adit on the south side of the vein about 300 yds. west of Bryn-y-Tail Farm, but this has been closed again for some time.

The barytes occurs in a vein which is said to be 12 ft. wide at the surface, and which appears to be connected with the lode at Pen-y-Clyn and the Van Mine further to the east.

The barytes varies much in character. Good white can be picked out, but the bulk shows much iron-staining on the surface. Quartz is fairly common and a small quantity of galena is present.

Good, clean barytes is said to have been obtained on the opposite side of the river on the slope of Pen-y-Gaer, in what is probably an extension of the same vein.

The barytes, in the crude state, was sent by road to Llanidloes, a distance of 3 miles.

Fachwen Mine.

Fachwen Baryta Company, Ltd., Liverpool.

Situated half-a-mile north-east of Tregynon and five miles north of Newtown, Montgomeryshire.

Maps.—One-inch New Series Ordnance, 151; Old Series Geological, 60 S.E.; six-inch Montgomeryshire, 29 S.W., Ord.

This mine has been working for about a year, although some work had been done before the present company took it over.

The vein runs nearly north and south through slaty Silurian rocks, and is almost vertical or with a slight underlie east.

The open-cast is about 100 ft. in length and about 40 ft. deep.

It has been reopened for a distance of about 36 ft. and a shaft has been sunk 15 ft., at the bottom of which the vein is 3 ft., and at the floor of the open-cast, 2 ft. in width.

Some of the spar is good white, but much of it is mixed with quartz and somewhat iron-stained.

Reserves cannot be estimated as the mine is not sufficiently developed. About 30 tons a week could be produced.

Gorn Mine

Welsh Van Mining Company, Ltd., Llanidloes.

Situated $1\frac{1}{2}$ miles east of Llanidloes.

Maps.—One-inch New Series Ordnance, 164; Old Series Geological, 60 S.W.; six-inch Montgomeryshire, 48 N.W., Ord.

At this mine there are two veins in the Silurian slates. The principal vein runs approximately east and west, and has been worked from a number of old shafts along the southern flank of of Gorn Hill. It yielded galena, zinc-blende and witherite.

The other vein branches off south-westwards from the eastern end of the principal vein, close to a level, and is said to consist almost entirely of witherite and barytes. As far as can be judged from the dump, witherite is the more abundant mineral. The vein is said to be about 8 ft. wide where the level meets it, but its extent has not been proved.

The two minerals appear to be somewhat closely intergrown, but are fairly pure when separated.

Dolwen Station on the Cambrian Railway is about 2 miles distant.

The principal vein has yielded large quantities of galena, but work ceased nearly 50 years ago. Barium spars are not known to have been produced commercially from either vein. The level

was opened up in 1912–13, but nothing further was done, and the entrance is now closed.

The mine is conveniently situated as regards water-supply.

Pen-y-Clyn Mine.

Welsh Van Mining Company, Ltd., Llanidloes.

Situated 2 miles N.W. of Llanidloes.

Maps.—One-inch New Series Ordnance, 164; Old Series Geological, 60 S.W.; six-inch Montgomeryshire, 41 S.E., Ord.

This mine has not been worked for many years, and the thickness and extent of the vein are not known. Apparently there has been no commercial production of barium minerals.

The vein seems to be one of the set of veins which is worked for lead-ore at the Van Mine; it courses about W. 20° S. through Silurian slates and grits, and is possibly connected with the lode of Bryn-y-Tail (p. 89). It is expected that the levels of the Van Mine will strike the old workings of the Pen-y-Clyn Lode.

Witherite is abundant in the tips from the old level and blocks of considerable size can be obtained. It is said to have accompanied the lead-ore in large masses, containing cavities lined with well-developed crystals. The mine was remarkable for the purity of its galena.

A mineral railway connects the Van Mines with Caeraws on the Cambrian Railway.

Vale of Towy or Bryn Towy and Nant Mine.

On the left bank of the Towy River, 1½ miles east of Carmarthen.

Maps.—One-inch New Series Ordnance and Geological, 229; six-inch Carmarthenshire, 39 N.E., Ms.

The vein which has been worked at this mine crosses an anticline of Arenig grits, its southern extremity entering the area of the overlying Arenig shales. It extends from the main road to a point east of Nant in a direction S. 20° E., then swings round gradually to the south-east. Its surface position is marked by old workings, and by a lateral displacement which it effects in the rocks.

The main portion of the lode underlies east at an angle of 10° to 30° with the vertical, but to the north two shafts, sunk on the western side of its surface position, suggest either that it has changed its underlie or has thrown off a westerly branch from a point about 100 yds. north of Nant.

The vein consists of galena (to a certain extent argentiferous) with a little copper pyrites and zinc-blende, in a gangue of barytes and quartz. The barytes is pure white and crystalline, and forms a large proportion of the gangue. There is said to be a width of 6 ft. of barytes in places.

A level has been driven on the vein from a point about 100 yds. south of the main road which runs along the south bank of the River Towy, and there are extensive tip-heaps on the east side of the vein, extending for 200 to 300 yds. from the main road. In these heaps there are large quantities of barytes mixed with calcite, vein-quartz and grit.

About 100 yds. W.S.W. of the old level the shaft known as Bonville's Shaft has been sunk to a depth, as supposed, of 80 fms. Some 150 yds. to the south-east, at the Engine House, there is another shaft sunk vertically for 20 fms., and in the lode for 104 fms.

There are several small pits on the vein to the south of this point; they extend as far as two shafts on the east side of the vein 200 yds. east of Nant, where the lode underlies east. The more northerly shaft struck the lode at 20 fms., proving it to hade at 1 in 3 from the vertical. Southwards again there are a few small pits on the vein, with indications of much barytes.

The total length of the vein is about two-thirds of a mile.

The distance from the mine to Carmarthen Railway Station is a mile and a half on a good road. The River Towy is tidal to a point about a mile above the mine.

The mine has been worked solely for lead-ore. The first authentic records appear under the name of the "Vale of Towy Mine," and mining returns show that for the 14 years, 1852–1865, 6,286 tons of dressed ore were sold.

In the years 1866–1881 the mine was worked intermittently under the name of "Bryn Towy and Nant." The last return (1881) gave two tons of dressed ore, with a value at the mine of 16*l.* The amount of ore raised between 1866 and 1881 was exceedingly small, in fact never as much as 10 tons in any year; but in 1873 four tons gave three tons of metallic lead and 18 ozs. of silver. The mine has not been worked since 1881.

It is not possible to estimate the amount of the minerals available in the mine, but the tip-heaps are large and contain a high percentage of barytes.*

Cystanog Mine.

On the left bank of the Towy River, two miles east of Carmarthen.

Maps.—One-inch New Series Ordnance and Geological, 229; six-inch Carmarthenshire, 39 N.E., Ms.

Two veins have been worked; both cross an anticline of Arenig grits (forming the hill Allt Cystanog) in a general southern direction.

The western vein does not appear to carry barytes.

The eastern vein runs S. 5° W. for about half its course, and then swings round to S. 20° E. in a similar manner to the "Vale

* "The Country around Carmarthen" (*Mem. Geol. Surv.*), 1909, pp. 152–154.

of Towy " Lode, the change of direction, as it appears in the outcrop, being due partly to the form of the ground. In the grits and conglomerates it carries galena, usually argentiferous, in a gangue of barytes and vein-quartz with a little copper pyrites, zinc-blende, and fahl-ore. At the southern end, however, where it enters the overlying shales, the galena, especially in depth, is mixed with an increased proportion of copper pyrites and zinc-blende, in a gangue of chalybite and vein-quartz.

Judged from the tips at the entrance to the levels on the north side of the hill, the barytes is white, crystalline and free from foreign material. Some of the masses are as much as a foot in diameter.

Galena was taken from the western vein by a level driven in from the road about 500 yards east of the " Vale of Towy " Mine, for a distance of 110 yds.; an air-shaft was made by working the vein to the surface at a point 65 yds. from the adit-mouth.

In the eastern vein the old workings consisted of shallow pits on the outcrop, and of a level driven in on the vein from the road.

In 1890 this deep adit (No. 1) was continued for a distance of 570 yds. from its entrance, and two levels were driven on the vein on the north side of the hill, one above the other. The lower of these (No. 2) starts 100 yds. south of the road and extends 400 yds. along the lode; the upper (No. 3) is shallow, and was driven for a distance of 65 yds.

On the south side of the hill the " Penlan Levels " were driven northwards. " Penlan No. 1 " is higher in the vein than No. 2 of the north side, and has a length of 120 yds. " Penlan No. 2 " is very shallow and 80 yds. in length, having been worked to the surface on the top of the bank.

Subsequently a shaft was sunk on the eastern side of the vein, at about 55 yds. from its surface-position, and was carried to a depth of 52 fms. in mudstones. At 40 fms. a crosscut was made to the deep adit (No. 1), and from the bottom of the shaft a crosscut struck the vein at a point 30 yds. west of the shaft. The vein was followed at this level in a north and south direction for 110 yds.

The ore consisted largely of galena, with an average of 6 ozs. of silver to the ton of metallic lead.

The mine is presumably unwatered down to the level of the deep adit No. 1, but below this it would probably be necessary to use pumps.

The same remarks as to transport facilities apply as in the case of the " Vale of Towy " Mine.

The surface-workings and the deep adit No. 1 constituted the Cystanog Mine, which was closed in 1864. In 1890 the Carmarthen Lead Mining Syndicate recommenced work on the east lode, and during the period from 1890–1902 drove the levels into Cystanog Hill from north and south, as described above. The first returns of lead-ore sold were made in 1892, and the output continued fairly steady until 1902, but in 1903 work

ceased. It is reported that barytes was brought out from No. 1 level (on the north side of the hill) and ground for paint, etc., at a mill some way beyond Carmarthen.

The lead-ore has probably been largely worked out down to the level of the deep adit, but below this there is no doubt much virgin ground. There is also in all probability a large quantity of barytes left in the old workings.*

Llan-gan Mine.

Situated ¼ mile S. of the village of Llan-gan.

Maps.—One-inch New Series Ordnance and Geological, 262; six-inch Glamorgan, 41 S.W., Ms.

The vein here worked is in Lias.

At Gelli Araul there is a small tip-heap containing fairly pure barytes, crystalline and in part of a violet tint. There is also a little barytes near the old engine-shaft.

The mine was worked by a shaft which passed through Liassic and Rhaetic conglomerates to a depth of 150 ft. without touching the Carboniferous Limestone.

It is situated about 4 miles by road from Cowbridge and about the same distance from Bridgend.

No work has been done for many years. In the years 1877 and 1878 the returns gave 99 and 42 tons of lead-ore respectively. No barytes seems to have been sold.

3.—Devonshire.

Teign Valley Mine.

Devonshire Baryta Company, Exeter.

Situated three-quarters of a mile west of Christow Station, on the north side of a little valley running from that of the River Teign towards Bridford.

Maps.—One-inch New Series Ordnance and Geological, 325; six-inch Devon, 91 N.E., Ord.

The country-rock is soft black Culm Measure shale with some beds of chert.

The works were started in 1876. The barytes lode was found during a search for silver-lead-ore.

In the face of the quarry where the barytes occurs, the rocks are much shattered, and cemented by barytes. The best quality barytes is found, however, in a definite vein running north and south, and dipping at a steep angle to the west. Here it occurs for the most part in botryoidal form, in kidney-shaped masses up to 6 ft. in diameter. It is fairly clean, but generally of varying shades of yellow and pale brown. These give a streaky appearance to the spar; which is then known by the workmen as

* "The Country around Carmarthen" (*Mem. Geol. Surv.*), 1909, pp. 152–154.

" bacon-ore." In other parts the barytes is massive and whiter than the " bacon." Crystals occur sparingly and only on the edges of the lode. Apart from colouring matter, impurities are seldom met with. Traces of silver-lead-ore are occasionally found. Barytes, when it occurs as a cement in brecciated killas, is for the most part of no commercial value.

The mineral is worked from an open quarry some 100 ft. in height, the vein being about 30 ft. wide. Formerly levels were driven at various depths down to about 40 fms. and a shaft sunk to 70 fms. At that depth the lode yielded a whiter mineral than at the surface, but was considerably narrower. One of these levels which opens near the grinding mill is now used for conveying the barytes from the quarry, the mineral being shot down an ore pass, in the floor of the quarry, to this level and trammed out.

Before the war the output averaged about 1,600 tons but this rose to about 3,000 tons in 1920.

The mineral is crushed to a fine gravel, in a chilian-mill worked by a water-wheel, and the fragments of killas and other impurities picked out by hand. The cleaned material contains on an average 96 per cent. of barium sulphate.

The mills are at Exeter. The ore is spread over plates, heated by steam, and again picked over by hand. When dry it is milled to a fine greyish powder. The bulk of the product is sold in Bristol. Bleaching has been tried, but was found to be unprofitable.

4.—Somerset.

Cannington Park (Rice's Wood and The Beacon).

B. G. Hamblin & Co., Bridgwater.

Situated at Cannington Park, four miles north-west of Bridgwater.

Maps.—One-inch New Series Ordnance and Geological, 295; six-inch Somerset, 49 N.E., Ord.

The barytes occurs in many veins intersecting the Carboniferous Limestone, and varying in width up to 2 ft. The veins show a comby structure with frequent vugs containing crystals. The spar is chiefly salmon-pink in colour, but is sometimes white.

Where the veins become narrow the crystalline barytes is replaced by redstone which is composed chiefly of quartz with calcite and specks of malachite, and usually some fragments of the country-rock.

The spar is excavated by narrow opencast workings about 30 ft. deep, following the veins, but below this depth the barytes has not been worked.

The ore is hand-picked, cleaned with wire brushes, after which the pink is separated from the white variety.

The raw material is ground in mills at Cannington, or at Spaxton, and the product carted by road to Bridgwater Station, a distance of 5 miles.

Work was commenced on these deposits early in 1916, and during the war over 5,000 tons of barytes were obtained. The output is now between 15 and 20 tons per month.

The Somerset Spar Company owns adjoining property. A large quantity of barytes has been quarried and accumulated in a dump from which it is withdrawn at intervals and sent to the mills, but the quarries are not being worked.

CHAPTER V.

THE MINES OF SCOTLAND.

General Account.

Barytes is a common constituent of many Scottish mineral veins, but often it is either present in small quantities, or too much mixed up with impurities to be of economic value. Some of the veins, which consist almost entirely of barytes, have been worked. Witherite, on the other hand, is one of the rarest of Scottish minerals, and until its recent discovery in the west branch of the New Glencrieff vein at Wanlockhead its presence in Scotland was uncertain. There is no record when barytes was first worked in Scotland, but Mr. Houston, manager of the Muirshiels Mine, states that the journals for that mine had been kept for about 140 years. The Glen Sannox Mine in Arran was opened up prior to 1841, and is mentioned by Ramsay.* The first official record of the working of barytes in Scotland is to be found in the "Mineral Statistics of the United Kingdom" for 1853, in which year 600 tons were wrought at the Glen Sannox Mine. Seventy tons are recorded as having been produced in Kircudbrightshire in 1856. No official figures are available for the years between 1862 and 1895, but the Arran and Kircudbrightshire mines are known to have been closed down. The Muirshiels Mine, however, remained working intermittently during that period, and continued as the only working barytes mine until 1915. In that year, however, owing to the scarcity produced by the war, efforts were made to increase the home supply of the mineral. Under these circumstances, some of the old mines were reopened, and new mines were started on hitherto unworked veins. A list of mines at which barytes has been worked is given below, together with other general information concerning them.

Details of Mines.

Muirshiels Mine.

The mine is situated on Queenside Muir, on the south side of the Calder Water, and at an elevation of from 900 to 1,000 ft. It is about 7 miles from Lochwinnoch Station (G. & S.W. Rly.), which is at an elevation of about 100 ft. A good road extends to the works at Muirshiels, but from there to the mine, a distance of about 2½ miles, there is only a cart track.

Lessees The Muirshiels Mineral Company, Lochwinnoch.

Maps.—One-inch Ordnance and Geological, 30; six-inch Renfrew, 10 N.W., Ms.

The mine appears to have been first opened up soon after the middle of the 18th century, and from that time to the present

* Ramsay, A., "The Geology of the Island of Arran," 1841, p. 23.

day, with varying success, it has been more or less in continuous operation.

The output of the mine for the first hundred years or so is unknown, the first official mention of the mine being for the year 1895; from then the figures published in the Home Office Statistics are as follows :—

Year.	Barytes.	Value at the Mine.	Year.	Barytes.	Value at the Mine.
	Tons.	£		Tons.	£
1895 - -	600	90	1908 - -	869	217
1896 - -	700	175	1909 - -	1,021	510
1897 - -	1,000	250	1910 - -	1,068	500
1898 - -	1,100	275	1911 - -	1,120	560
1899 - -	927	162	1912 - -	700	350
1900 - -	879	220	1913 - -	669	100
1901 - -	1,070	214	1914 - -	404	101
1902 - -	600	120	1915 - -	302	50
1903 - -	694	243	1916 - -	263	66
1904 - -	520	260	1917 - -	192	96
1905 - -	877	438	1918 - -	115	58
1906 - -	997	498	1919 - -	Nil	—
1907 - -	900	450	1920 - -	95	—

The vein occurs in an area of almost flat flows of greenish basalt of Calciferous Sandstone age. It trends 10° to 15° W. of N., is practically vertical, and varies from 6 ft. to 16 ft. in thickness. The barytes is of a creamy to pink colour, and sometimes perfectly white when broken open, though the fragments are generally iron-stained. In structure the vein-stone is comby or composed of parallel prisms growing at right angles to the walls. There is also a well-defined longitudinal banding produced by parallel white and pink strips. A little quartz occurs, especially near the cheeks, and several horses or inclusions of country-rock are distributed through the vein.

The workings extend from the stream known as the Calder Water for a distance of 600 to 700 yds., and are evidently old. They began as open-cast workings, and as the vein was followed up the hill attained individually in places a depth of 50–70 ft.

The quarries are at three levels, the lowest being the first worked and nearest the stream, the second about 50 ft. above the first, and the third about 30 ft. above the second. Hence the successive quarries are carried into the hill face as a series of steps. At the ends of the second and third open-works, mines have been driven into the vein at the level of the floor of the workings. The level at the second open-cast is about 100 yds. long, and the roof in many places has been stoped out to a height of 20 ft. or more. That at the south end of the top open-cast is somewhat shorter, and the stoping has been carried to a height of from 30 to 40 ft. There has also been a certain amount

of underhand stoping, and the bottom of the level is now filled up with rubbish. Little work has been done during the last few years and the mine was closed for the winter of 1920, but preparations were then being made to reopen it in a short time. The amount of barytes visible in the face is small, and at the second level it thins away to a few feet in the roof. Further to the south the vein is said to have been traced for a considerable distance at the surface. The northern extension has not been proved beyond the Calder Water, but a bore put down to a depth of 70 ft. below the sole of the lowest open-cast is reported to have passed through barytes all the way.

After mining the barytes is carted to the grinding-mill, which is situated at Muirshiels and driven mainly by water, of which in winter there is abundance, but sometimes a shortage in summer. Steam is used to drive the small mills that grind the final product, and may also be employed for the rough barytes in cases of urgency. The mill is fitted with three grinders of the type known as "arrastras." These are cast-iron vats about 8 ft. in diameter and floored with blocks of granite or whinstone carefully fitted together. Upon this floor, blocks of granite measuring 2 ft. by 1 ft. 6 ins. by 1 ft. 6 in., with their lower surfaces smoothed, are dragged round. One ton of "ore," hand-broken to 2-in. size, is placed in the vat with water, where it is ground for a period of 24 hours, by which time it is reduced to an impalpable powder. The grinding is then stopped and the charge run off into a settling tank. Subsequent treatment depends on whether the product is to be sold as "white" or "grey" barytes. The "grey" variety, which is pinkish in colour, contains all the impurities of the original stone. It is pumped out of the tank in a wet condition, and dried over a brick-work stove in a layer 5 to 7 in. thick. When dry it is dug out in lumps, passed on to the mill driven by steam, and there reduced to an incoherent powder. It is then filled into 2 cwt. bags and sent to Glasgow. The "white" variety is made by treating the ground material for 24 hours in a leaden cistern with fairly strong sulphuric acid heated by steam. One charge of acid serves for two or three one-ton lots of barytes. After this treatment the material is washed in another leaden vat with hot water and passed on to a wooden tank, where it is stirred up with cold water for some time, then allowed to settle and the water run off. After repeating this process three times the barytes is free of acid. To improve the colour a little blue pigment is added to the last washing-water. The material is dried over a stove, but not the same as that used for the "grey" variety. When dry it is dug out, passed through a mill, bagged and is ready for sale. A special grade of No. 1 white is made by drying on racks in a hot room for several days. During the process no exact measurements are made of the fineness or uniformity of the powder. This depends entirely upon the skill of the workman in charge of the grinding. The freedom of the finished barytes from sulphuric acid is judged

by the smell of the steam that is driven off when the powder is being dried over the stove. If any acid remains, it can easily be detected by the pungent odour it gives off when the powder is nearly dry. The mill has a capacity of nearly 2 tons a day. It might be run at three tons a day, but not continuously. The bleaching plant can treat one ton per day. More than one-half of the product is sold as grey barytes.

It is probable that the vein continues in depth, but to work it downwards would necessitate pumping and haulage machinery. On the other hand, the mine might be worked forward along the vein, but it would be necessary to prove the ground first.

Glen Sannox Mine (Arran).

The mine is situated about half a mile up the Glen Sannox Burn, access to it being obtained by an old cart track which leaves the road about 100 yds. south of the bridge over that burn.

Prop. : The Marquis of Graham.
Lessees : Messrs. Martin Barrowman & Co., Glasgow.

Maps.—One-inch Ordnance and Geological, 21; six-inch Argyll and Bute, 238 N.E., Ms.

The occurrence of barytes at this locality has been recognised for about 120 years, and the vein was known to T. Pennant*, R. Jameson†, J. Headrick‡, J. Maculloch§ and others.

When Ramsay‖ visited Arran about 1840, the mine was being worked, and dressing and washing plant had then recently been erected. He describes the process for the manufacture of the finished barytes, which seems to have been almost identical with the method now followed at Muirshiels.

He also describes a method whereby the barytes was stained yellow by means of chromate of lead.

From 1840 to 1862 the mine appears to have been in continuous operation, but soon afterwards it was closed and the mill dismantled.

The output of barytes from 1853 to 1862 was as follows¶ :—

Year.	Tons.	Year.	Tons.
1853 - - -	600 19 cwts.	1858 - -	550
1854 - - -	550 -	1859 - -	—
1855 - - -	550 -	1860 - -	550
1856 - - -	550 -	1861 - -	625
1857 - - -	—	1862 - -	730

* "A Tour of Scotland," Vol. ii, 1790.
† "Mineralogy of the Scottish Isles," 1800.
‡ "View of Arran," 1807.
§ "Western Isles," 1819.
‖ Ramsay, "The Geology of the Island of Arran," 1845, pp. 23–24, which is incorporated in a book entitled "Novelties in Experimental Science," 1845.
¶ "Mineral Statistics of the United Kingdom."

In 1918 the mine was reopened, but little work was done. In 1920, however, about 300 tons of excellent barytes were raised and exported from the island. A new shaft is being sunk, a railed incline laid down from the mine to the shore, and general preparations for working the old mine and other newly-discovered veins on a large scale are in progress.

The country-rock consists of interbedded sandstones, conglomerates and red mudstones of Lower Old Red Sandstone age. Near the old mine the main vein is well exposed where it crosses the Glen Sannox Burn. It is much broken up, trends almost due north and south, and dips westwards at a high angle. About 50 yds. further down the north side of the burn, another vein can be seen, which is about 2 ft. wide and trends north-west. On the hill-side to the north and north-west of the mine, no less than four veins have recently been discovered. They all trend about north-west and carry from 2 to 5 ft. of barytes. In all probability one of these is the continuation of the main vein, but as all are exposed within a small area it is impossible to decide which one. From observations made on the main vein, one gathers that it is of a very variable nature. Thus, for instance, where seen crossing the burn, it contains more broken country-rock than barytes, although the sole of the level, driven only a short distance below, shows from 8 to 9 ft. of good barytes. If the veins recently discovered should prove to be of a similar nature, then one or all of them may contain valuable deposits of barytes.

Two shafts have been sunk, one on either side of the burn, which communicate with one another by a level driven under the burn at a depth of about 20 ft. From the southern shaft the level has been continued 60 yds. further to the south. At the northern shaft the main vein is seen to be cut by another vein which trends north-west; the level has been driven along this other vein. At and about the junction of the two veins, there were several false walls, and the barytes swelled out into a pocket over 12 ft. in width.

Gass Water Mine.

The mine is situated at an elevation of about 1,100 ft. on the hill-side to the north-east of the Gass Water, and just over 2 miles up stream from the railway. Access is obtained by an old mineral line which leaves the railway about half-a-mile east of Cronberry Station, and extends to a point about 2 miles almost due west of the mine. From this point a narrow-gauge bogey line has been laid the whole way to the mine, and an aerial ropeway is in process of being fitted.

Prop. The Marquis of Bute.
Lessees. The Hedworth Barium Company, Ltd., Newcastle-on-Tyne.

Maps.—One-inch Ordnance and Geological, 15; six-inch Ayrshire, 36 N.E., P.

The presence of veins of barytes at this locality has long been known. Several years ago the main vein was opened up by a trench at a point near where the mine is now situated, but little else was done, and the work was soon abandoned. About the beginning of 1917 boring operations were commenced by the Hedworth Barium Company at the site of the old workings, and the position of the vein at the surface was proved by a series of trenches. Open-cast mining operations started in 1918. The output is as follows :—

1918 - - -	None sold but several hundred tons raised.
1919 - - -	3,097 tons valued at £6,968.
1920 - - -	4,635 tons.
1921 - - -	500 tons to March, and 700 tons in stock.

The country-rock consists of red, white and yellow sandstones with associated pebbly and marly beds of Upper Old Red Sandstone age. The vein dips to the south-west and is associated with a line of crush which has been traced from the Boghead Burn at the north-west, to where it crosses the Gass Water about two and a half miles to the south-east. The infilling of the vein is seen to vary along its course from a breccia of sandstone fragments with a few strings of barytes to a solid mass of barytes 26 ft. in width, varying in colour from pink to white or water-clear.

About 200 to 300 ft. to the south-west a parallel vein is exposed in the beds of some of the small burns which flow down the hill-side. When driving the adit level crosscut, it was found to be about 4 ft. wide and to consist of hard pink barytes. The vein has been opened up over a distance of 400 ft. by an open-cast which varies in width from 13 ft. at the south-east and to 26 ft. at the north-west. The depth averages from 4 to 6 ft., and the whole working is in barytes. A crosscut adit level which has been driven from a point 425 ft. to the south-west meets the vein at a depth of 81 ft. From the point of intersection a level, 6 ft. by 6 ft., has been driven on the foot-wall side in both directions for a total distance of 280 ft. all in barytes. At the north end two crosscuts, which have been driven to the hanging-wall, show the vein to retain the thickness seen at the surface. All the barytes has been sent away in the crude state, but it is proposed to erect a dressing plant near the mine.

Roy Goe Mine.

(*Idle.*)

The mine is situated on Clyth Shore at Roy Goe about one-third of a mile south of Clyth Smithy—one mile south-east of Occumster Station and 12 miles S.S.W. of Wick.

Maps.—One-inch Ordnance and Geological, 110; six-inch Caithness, 34 S.W., Ms.

The vein has been known for a considerable number of years, and a few trials were made on it in 1914. It was taken over by the Hedworth Barium Company in 1915 and was worked

by them till 1918 when it was abandoned, since to all intents and purposes it was worked out. The output for the period is as follows :—1915, 40 tons; 1916, 1,411 tons; 1917, 988 tons; 1918, 8 tons.

The vein occurs in an area of Caithness Flags of Old Red Sandstone age. It has a north-westerly trend, dips to the north-east and is associated with a line of weakness which has given rise to the indentation of the coast line known as Roy Goe. As seen in the cliff the thickness varies from 3 to 4 ft., but in the mine it increases to 9 ft. The barytes is white in colour but tends to weather with a yellowish tint.

The mine was worked by three levels. The lowest is driven from the beach a distance of about 200 ft. The next level is 50 ft. above and is 400 ft. long, and the top level, 25 ft. higher, was driven about 275 ft. All the workable ground above the intermediate level has been removed practically to the surface, but only a little stoping was done at the beach level.

Barlocco Mine.

(*Idle.*)

The mine is situated on the west side of the Barlocco Burn, and about 200 yds. north of Barlocco farm. The nearest railway station is Kirkcudbright some 7 miles to the W.N.W. Of this distance the road is good for about 5 miles and fairly good for the remainder.

Maps.—One-inch Ordnance and Geological, 5; six-inch Kirkcudbright, Old Series 51 S.E., Ms.; New Series 56 S.W., Ms.

The occurrence of veins of barytes at this locality has long been known. On the shore near Portmary* there is a natural arch made of this material, which goes locally by the name of the Hangit Man. The mine was opened before 1856 and the output from that time till 1862 was as follows† :—1856, 72 tons; 1857, 72 tons; 1858, 125 tons; 1859, — tons; 1860, 150 tons; 1861, 175 tons; 1862, 150 tons.

During this period the barytes was carted a distance of 5 miles to a dressing plant at Auchencairn. Soon after 1862 the mine was closed and it remained abandoned until about 1914, when it was reopened and prospected.

In 1916 it was taken over by the Barlocco Mining Company. A new dressing plant was erected, and the finished product was taken to Kirkcudbright by motor. The output for this last period of working was as follows :—1916, 72 tons; 1917, 559 tons; 1918, 700 tons; 1919, 450 tons; 1920, 282 tons.

The country-rock consists of Silurian slate. Two parallel veins about 100 yds. apart, trend W. 8° N. and dip southwards at high angles. The more southerly is seen at the mouth of a level on the road-side about 200 yds. from the farm house.

* "The New Statistical Account of Scotland," 1845, vol. iv. Kirkcudbrightshire, p. 361.

† The figures probably include those from the neighbouring mine of Auchencairn.

It is three feet wide at the surface but expands to eight feet in the working, which is small and consists only of a short level. The bulk of the barytes is pink, but occasional patches are of clear white material. A small quantity of the pink variety was wrought and sold. The main operations have been on the more northerly vein, which varies from one and a half feet to seven feet in thickness. The infilling consists principally of white barytes which is often spoilt by numerous fragments of country-rock, or by green staining due to ores of copper.

Three levels have been driven along the vein. The top one is about 70 ft. above adit, and practically all the workable ground between adit level and the surface has been removed. The adit level has been taken a distance of 700 ft. About 600 ft. in, a winze has been sunk to a depth of 90 ft. in barytes, and from the bottom a level driven back under the adit level for a distance of 170 ft. At the foot of the shaft, and for 40 ft. along the level the barytes varied from 3½ ft. to 6½ ft. in thickness. The water from the low level was pumped to adit by means of a pulsometer.

After mining the clean barytes was hand-picked; the mixed material containing a good deal of country-rock was crushed and passed through two jigs which separated a further quantity of barytes. This material was first ground by means of a pair of vertical Scotch mills and then finished in horizontal mills. A bleaching vat and drying kiln to treat three tons were also used.

Auchencairn Mine.

(*Idle.*)

The old mine is situated about one quarter of a mile S.S.W. of the farm of Airds and 120 yds. from the coast. A good road exists from a pier at Auchencairn to Airds, but from there to the mine there is only a cart track.

Maps.—One-inch Ordnance and Geological, 5; six-inch Kirkcudbright, Old Series 52 S.W., Ms.; New Series 56 N.E., S.E., Ms.

The mine appears to have been opened about 60 years ago, and 700 tons of barytes are said to have been taken out of one pocket.

The country-rock consists of hard reddish grit of Calciferous Sandstone age. The vein trends E.N.E. and dips to the north. About 2 ft. of barytes can be seen at the surface, but the thickness increases in the mine. About 1915 the old workings were re-examined and a few tons of good platy pinkish-white barytes were raised, but little else was done. A few hundred yards to the west there is an old copper mine, which is drained by an adit extending to the sea-coast. A small quantity of barytes lies on the dump at the mouth of the adit. In all probability it was obtained from the westerly extension of the Auchencairn vein when it was cut in the adit.

Aberfoyle Mines.

(*Idle.*)

The old mines are situated about 2½ miles south-west of Aberfoyle Station. The larger mine is on the south-west slope of Arndrum. The smaller one occurs about 600 yds. north-west of Gartloaning farmhouse, and about a mile E.S.E. of the Arndrum mine.

Maps. — One-inch Ordnance and Geological, 39; six-inch Perth, 129 N.E., S.E., Ms.; Stirling, 7 S.E., Ms.

It appears that the mines were working about 1882, and stopped about 1887. The barytes was sent to Gartmore and thence to Glasgow, but the output is not known. Work was apparently discontinued owing to the increasing depth of the mine, trouble with water and scarcity of "ore." It is not probable that the veins continue in workable condition to the north or south.

At Arndrum operations have been carried on by open-cast workings on the two almost parallel east and west veins, which are about 70 yds. apart. The country-rock is of Lower Old Red Sandstone age, and consists of a series of interbedded conglomerates and dark red mudstones, with one or more flows of rotten, vesicular andesite. The veins lie immediately south of the great Highland Border Fault, and they cannot be traced to the edge of the Old Red Sandstone area. Neither are there any signs of their extension into the Highland rocks which lie to the north of the fault.

The West Vein trends N. 40° W., and dips south-west but is almost vertical. It occurs on the ridge of a low hill, and has been worked open-cast to a maximum depth of about 30 ft. The width of the open-cast varies from 12 or 15 ft. at the top to 4 ft. at the bottom, but it is probably wider than the original thickness of the vein. The bottom of the working is full of water and there is no good exposure of barytes, but the thickness of that material there, cannot have averaged more than 3 ft. On the spoil-heaps there is some creamy and reddish barytes, often mixed with fragments of conglomerate, and sometimes stained green by ores of copper. When followed downwards the vein apparently thinned out and there is no evidence that it extends beyond the limits of the old working.

The East Vein occurs about 70 yds. to the east, and has been worked across the back of the same ridge. It trends N. 20° W. and dips at about 80° to the south-west. The workings are on a considerable scale and the main open-cast is about 90 yds. long with a maximum depth of 40 feet at the centre. The width of the open-cast varies from 15 to 20 ft. at the top to 3 to 6 ft. at the bottom. Some barytes mixed with fragments of conglomerate is seen on the foot-wall, but the bottom of the excavation is filled with blocks fallen from the wall. This part of the mine is reputed to have been worked to a depth of 120 ft. Northwards and southwards the workings become small, and the vein thinner and more mixed with country-rock. At the south end there is a small quarry where the vein splits up and thins to a few inches.

At the north end of the main working the vein branches into three parts, which have all been tried, especially the one farthest west, but in a few yards they all die out.

On the slopes of the valley to the north, and 40 ft. or so below the bottom of the main workings an adit level was commenced. It is nearly dry and the debris from it contains practically no barytes. Trials have been made on the north end of the vein but have failed to prove that it continues in workable thickness. The spoil-heaps contain comparatively little barytes, but some of it is of excellent quality, although other specimens contain small quantities of galena, copper-ores and quartz. The small size of the spoil-heap at the main working compared with that of the trial would indicate that most of the material worked was barytes of good quality.

Gartloaning Mine is situated on the north-east slope of a low hill about 600 yds. W. 40° N. of Gartloaning. The country-rock consists of interbedded dark red mudstones and gritty sandstones of Lower Old Red Sandstone age. The vein which has been worked open-cast trends W. 20° N. and dips south-east at 75° to 80°. The open-works extend over a distance of 85 yds. and descend the hill towards the north in three stages of 25 to 30 ft., 12 ft. and 10 ft. in depth. The southernmost working is the largest, being 45 yds. long, 10 ft. wide at the top and 3 ft. at the bottom. Good barytes of pinkish colour is to be seen on the cheeks of the vein.

The vein splits up and dies away southwards. On the north it has evidently been searched for by trial pits, but not found in workable quantity. As far as can be seen it seems to be less than 3 ft. wide at the bottom of these trials. The spoil-heaps show much sandstone with but little barytes, and no idea of the quality of the spar could be formed.

Smaller veins have been opened up at other localities further west, but have proved impersistent. Thin veins of barytes are also visible on the Drum of Clashmore, about a mile to the south-west.

Subsidiary Occurrences.

Perth and Clackmannan.

Numerous veins in which barytes is found as a gangue mineral occur along the southern slopes of the Ochil Hills between Bridge of Allan and Dollar. The positions of these veins are shown on the published one-inch Geological map, 39, but it is only near Blairlogie and Menstrie that any of them are large enough and sufficiently free from such impurities as quartz and copper-ores, to be of value as sources of barytes.

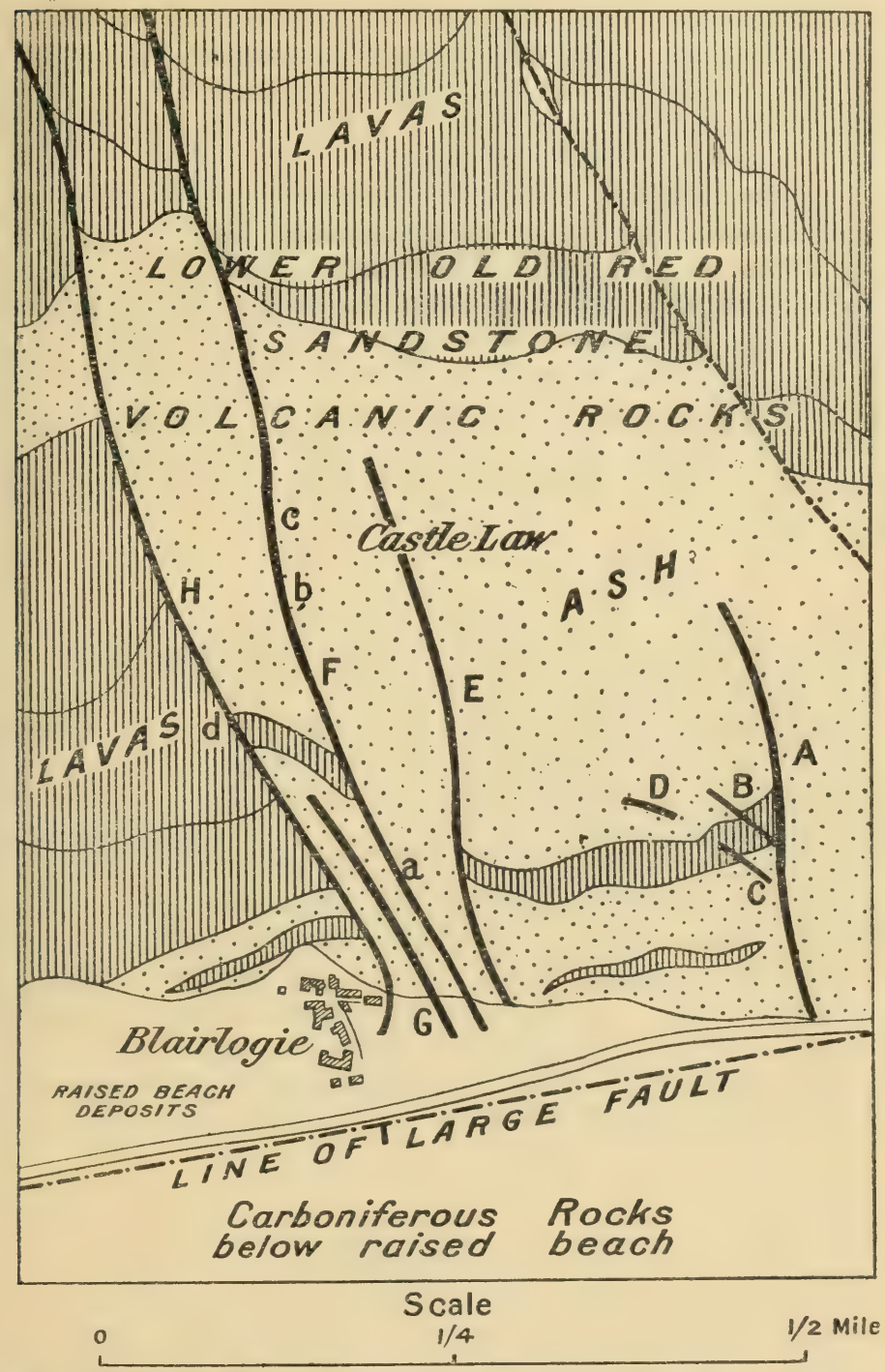
The country-rock consists of a series of interbedded lava-flows, ashes, and volcanic detritus of Old Red Sandstone age. The southern flank of the Ochil Hills is bounded by a large fault which trends about 50° E. of N., and throws down Carboniferous rocks on the south. Two sets of veins have been noted in the district, one trending a few degrees west of north and the other north-west, but it has not been possible to find out which is the older set, nor is the relation of the fault to the veins known.

Blairlogie Veins.

Prop. : Colonel Hare.

Maps. — One-inch Ordnance and Geological, 39; six-inch Perth and Clackmannan, 133 S.W., P.

Fig. 1. Map of the Blairlogie Veins.



The positions of the veins are shown on the map (Fig. 1). The five principal veins, A, E, F, G and H, trend N.N.W.; while the three subsidiary ones, branching off from A, trend in a W.N.W. direction. The easternmost vein, or A, occurs near the mouth of an old adit on the hill-side about 600 yds. E.N.E.

of Blairlogie. It hades to the west, and consists of about two feet of intermingled pink barytes and quartz containing numerous green stains due to copper-ores. The three subsidiary veins, B, C and D, carry the same minerals, but are thin and not continuous.

The next of the principal veins, E, passes 200 yds. east of Blairlogie. It is not seen at the surface but its presence is inferred from the occurrence of a narrow gully strewn with blocks of pink barytes. The vein appears to be wide, but it has not been opened up. The third vein, F, is seen in the crags about 150 yds. north-east of Blairlogie. It dips to the east, and at the point marked *a*, where it has been worked for copper-ores, there are about four feet of barytes. At *b* it is much broken up and consists of a few small strings of barytes up to one or two feet in thickness. At *c* it has expanded and shows twelve feet of barytes with some quartz. The fourth vein, G, occurs a few yards further west and consists of about two feet of platy pink barytes. It has been worked for copper-ores. The last vein, H, occurs on the west side of the burn immediately behind Blairlogie House. At *d* it is from nine to twelve feet in thickness and consists of barytes with some quartz. This vein has been worked for copper-ores in a level on the side of the burn about 100 yds. behind the house.

Menstrie Vein.

Maps.—One-inch Ordnance and Geological, 39; six-inch Perth and Clackmannan, 133 N.W., N.E., P.

The vein has been traced as a fault from near Balquharn; one mile west of Alva, for a distance of four miles in a N.N.W. direction towards Glentyre Hill. It is known to contain barytes at two localities. The more southern is in a small burn about one-third of a mile W.N.W. of Colsnaur Hill, and the other on the sides of the Second Inchna Burn, a quarter of a mile further north. At the first locality the vein is about 8 ft. wide, and contains pinkish-white barytes much mixed with quartz and copper-ores. At the exposure in the Second Inchna Burn the vein forms a wall on the east side of a narrow gorge to which it runs parallel for a considerable distance. It contains a good deal of quartz, and up to 6 ft. of good fairly clean white barytes.

Argyllshire.

Strontian and Loch Sunart.

Practically all the lead-ore veins of this area contain barytes as their principal gangue mineral, but so far none of them has been worked for that material. A full account of the mines of Strontian and Lurga is given elsewhere.*

* "Special Reports on the Mineral Resources of Great Britain," Vol. xvii, The Lead, Zinc, Copper and Nickel Ores of Scotland (*Mem. Geol. Surv.*), 1921, p. 82

STRONTIAN MINES.

(Idle.)

Prop. : The Board of Agriculture for Scotland.

Maps.—One-inch Ordnance, 52; six-inch Argyllshire, 18 S.W., Ord.

The workings on the Strontian Main Vein extend from the West Whitesmith trials on the west for a distance of about 1½ miles to beyond the Bellsgrove open-cast on the east. The main workings are at the Whitesmith, Middleshop and Bellsgrove mines which lie respectively about half-a-mile N.W., N.N.W., and N.E. from Bellsgrove Lodge, and 4 miles by fairly good road from Strontian post office. Materials might be shipped by improving the old jetty which lies about half-a-mile beyond the post office.

At the West Whitesmith trials two veins carrying white barytes have been opened up by shafts and trenches. The more westerly of the trials, together with a vein of barytes trending 10° N. of W., which is also exposed about 100 yds. further east, appears to be on the continuation of the Strontian Main Vein. The other vein trends 10° S. of W., and the two probably meet at a point about 90 yds. east of the more westerly trial shaft.

The Whitesmith mine is situated at an elevation of from 900 to 1,100 ft., and is about half-a-mile by rough track from Middleshop. The vein varies from 4 to 12 ft. in width, trends a few degrees north of west and is almost vertical. The spoil-heaps at this locality contain several thousand tons of barytes, which is white in colour, platy and rather soft, with a tendency to a radiate arrangement of the crystals. It is mixed with a good deal of galena, but a large quantity of clean material could be hand-picked. At the Middleshop and Bellsgrove Mines the gangue of the vein contains a good deal of calcite and is of little use as a source of barytes, though a fair quantity lies in the dumps at Bellsgrove Lodge. The trials east of the Bellsgrove open-cast, however, show that the vein there consists principally of barytes, with some galena.

LURGA MINE.

(Idle.)

Maps.—One-inch Ordnance, 52; six-inch Argyllshire, 41 S.W., Ord.

The old mine is situated on the north side of Glen Dubh, and about a quarter of a mile up the small burn that flows a few degrees north of west from the ruins of Lurga, which are about five miles south-west of Liddesdale. It is reached by an old pack-horse track which joins the main road about 2½ miles from the mine.

The vein trends a few degrees north of west, dips south at 65°, and varies in thickness from 4 to 10 ft. It consists of barytes and quartz with interspersed galena and blende. About 50 yds. up stream from the mouth of the lowest level the vein is seen to split into two, and at one point the southern branch

contains about 4 ft. of good white barytes free from galena. The dumps are small and much spread out, but consist mainly of barytes.

Allt a' Garh Choire Bhig.

Maps.—One-inch Ordnance and Geological, 53; six-inch Argyllshire, 29 N.W., Ms.

Mr. Bailey* mentions the occurrence of a vein of barytes that is seen in a small gorge which empties into Allt a' Garh Choire Bhig, a tributary of Coire an Tubhair. It is about five feet thick, occurs in the centre of a north-west dolerite dyke, but does not extend at the surface for any great distance.

Ayrshire.

Muirkirk District.

Maps.—One-inch Ordnance and Geological, 15; six-inch Ayrshire, 31 S.W., P.

A thin vein of barytes is seen in the Garpel Water, just below the bridge where the old road to Sanquhar crosses the stream, and about two miles south of Muirkirk. It trends W. 20° N., is about 9 in. in thickness, and can be traced for only a few yards.

A number of veins of pink barytes can be seen crossing the Polwhannon Burn (six-inch Ayrshire, 37 N.W.), about four miles south of Muirkirk. They all trend E. 10° N., and are thin and valueless as a source of barytes.

Glengarnock.

Maps.—One-inch Ordnance and Geological, 22; six-inch Ayrshire, 8 S.W., P. and New Series, Ms.

A thin vein of barytes occurs in an old limestone quarry, now filled with water, in front of the form house of Crawfield, three-quarters of a mile eastwards from Glengarnock Station, and about 200 yds. east of the Kilbirnie Branch Railway. The barytes is of good quality, and the vein, which is about one foot wide, trends north-west, and appears to have been opened up by a trench for a short distance.

Lanarkshire.

Auchinstilloch District.

Maps.—One-inch Ordnance and Geological, 23; six-inch Lanarkshire, 37 N.W., S.W., P.

Several veins of barytes have been noticed in the Auchinstilloch district about six miles north-east of Muirkirk, and the same distance south-west from Lesmahagow. Access is difficult as there are no roads near the locality.

No. 1 vein, lies at the head of the Pockmuir Burn and consists of pink barytes containing numerous strings of hæmatite. It is about six feet wide, hades west, and crosses the burn in a north-west direction. The country-rock consists of Silurian mudstone and shale.

* "The Geology of Ben Nevis and Glen Coe" (*Mem. Geol. Surv*), 1916, p. 234.

Nos. 2, 3 and 4 veins are situated near the head of the River Nethan. No. 2 Vein is the most westerly; it trends north-west, is from 4 to 5 ft. in thickness and contains a peculiar kind of barytes which is soft and massive. Where it crosses the burn the vein contains about two feet of barytes with specks of galena. About 100 yds. to the north-west several tons of this material lie on the spoil-heap from a small shaft sunk to the vein. The country-rock is grey Silurian mudstone.

No. 3 vein, the middle vein, is much mixed with broken country-rock, though at one place there are two feet of pink barytes free from galena. It trends north-west. The country-rock consists of pink felsite intruded into grey mudstones.

No. 4 vein is the most easterly and is about six feet wide and much broken up. It consists of pink platy barytes mixed with a large amount of mudstones and grits. Near its centre a thin seam of hard massive barytes occurs, which like the rest of the barytes, carries a little galena.

No. 5 vein. This vein trends W.N.W. on the north slope of Nutberry Hill. It has been worked open-cast on a small scale for galena. Barytes occurs only in thin strings and is pink in colour.

No. 6 vein lies on the east side of a small burn between Meikle Auchinstilloch and High Monkshead. It trends north-west through rocks of Old Red Sandstone age. It varies from about six feet of fairly pure pink barytes at the south end of the exposure, to broken rock with only thin strings of barytes at the north.

All the veins except No. 6 are shown on the One-Inch Geological map, but with the possible exception of No. 2 none is of economic value.

Auchensaugh Hill.

Maps.—One-inch Ordnance and Geological, 15 and 23; six-inch Lanark, 42 N.W., S.W., P.

A vein containing a little barytes and trending north-west occurs in a burn running south-westward from near the top of Auchensaugh Hill, about 2½ miles north-west of Crawfurdjohn. In the Braidknowe Burn 1¾ miles north-west of the same place there are a few strings of barytes which course in the same direction.

A trial for barytes was made on a small vein exposed in the old whinstone quarry on the north of Pagie and one mile south-east of Douglas. As seen at the surface the vein was about one foot wide and consisted of good white barytes, but the workings proved it to be of small extent, and it was soon exhausted.

Linlithgowshire.

Hilderstone.

(*Idle.*)

Maps.—One-inch Ordnance and Geological, 31; six-inch Linlithgow, 5 S.E., Ms.

The mine is situated at the south-east corner of Cairn Papple Hill, about four miles south of Linlithgow and two and a half miles by road N.N.E. from Bathgate Station.

A full account of this mine is given elsewhere.*

In 1870† the mine was reopened and a shaft was sunk to a depth of 225 ft.; the section of the country-rock on the hanging-wall side of the vein was found to be as follows:—

	Feet.
Surface clay and stones	18
Sandstone	11
Fakes	37
Whinstone	16
Blaes	11
Limestone	54
Marl	42
Marl and Whinstone	36

Opposite the top whinstone the vein is about six feet wide and consists entirely of barytes. The barytes on the dumps ranges from pure white to pink in colour and is of good quality.

Forfarshire.

Forbidden Cave.

Maps.—One-inch Ordnance and Geological, 57; six-inch Forfar, 46 N.E., Ms.

The vein occurs in the face of the cliff at Forbidden Cave, which is situated about half-a-mile north-east of Carlinheugh Bay and 3 miles north-east of Arbroath. There is a good road to Arbroath from a point about one-third of a mile inland from the vein.

The vein trends north-east, dips south-east and varies in thickness from a few inches to 6 ft. of good pink platy barytes. It cuts across a small headland, and the sea working along the line of weakness has driven caves into it from both ends. At the mouth of the cave on the north side of the headland the vein is seen to be about six feet wide. It retains this thickness for a considerable distance upwards, but near the top of the cliff, which is about 100 ft. high, the thickness has diminished to 2 or 3 ft. When followed horizontally into the cave the barytes thins away again to a foot or so. Where seen at the cave on the south side it consists mainly of broken country-rock (Old Red Sandstone) with strings of barytes up to nine inches or one foot in thickness. Southwards and northwards from the headland the vein can be traced for considerable distances by the occurrence of thin strings of barytes on the face of the cliffs.

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* "Special Reports on the Mineral Resources of Great Britain, Vol. xvii, The Lead, Zinc, Copper and Nickel Ores of Scotland" (*Mem. Geol. Surv.*), 1921, p. 61.

† H. Aitken, "The Hilderstone Silver Mine, near Linlithgow" *Trans. Fed. Inst. Min., Eng.*, Vol. vi, 1893–94, pp. 193–198.

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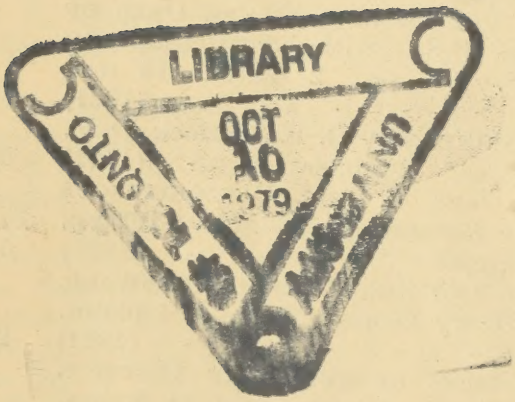
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